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VITAMIN AND MINERAL CONTENT OF CERTAIN FOODS AS AFFECTED BY HOME PREPARATION

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U. S. DEPARTMENT OF AGRICULTURE
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The research reported here represents the cooperative effort of a number of individuals whose skill and interest made the completion of these investigations possible. The research was conducted under the direction of Elsa Orent-Keiles, nutrition chemist.

In addition to the work of the authors, the following persons were immediately responsible for carrying out various phases of the work on chemical analysis:

Lillian I. Butler and Helen Diering Strock—calcium, phosphorus, iron.
Mary Latimer Mount and Margaret Koch Mead—ascorbic acid and related substances.
Doris Levy—thiamine.
Jane B. Greenwood, Gerda Siegel, and Margaret Attaya—riboflavin and nicotinic acid.
Joan Lorr—carotene.
Elizabeth Crofts Callison—bioassay of corn for vitamin A and thiamine.
Mildred Walters and Genevieve Ross Thomas—fat, moisture, ash.

The following persons participated in standardizing cooking procedures and in the preparation and cooking of food for analysis:

Grace E. Schopmeyer, Ernestine Garofalo Law, Ruth Bergren Anderson, Dawn Tuttle, Bernice Kluttz McGeary, and Soledad Payawal.

The Bureau of Plant Industry, Soils, and Agricultural Engineering identified varieties of potatoes and carrots and supplied snap beans for the study.

The Bureau of Animal Industry provided certain meats and poultry for these investigations and made meat cuts to provide special samples.

The Maryland Agricultural Experiment Station provided fresh lima beans and corn of known variety and maturity. The Georgia Agricultural Experiment Station furnished sweetpotatoes.

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VITAMIN AND MINERAL CONTENT OF CERTAIN FOODS AS AFFECTED BY HOME PREPARATION

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PURPOSE AND PLAN OF STUDY

Cooking often takes a heavy toll of vitamins and minerals before food reaches the home dinner table. Those who calculate the nutritive value of diets have long realized that the figures given in food-composition tables are usually much higher than the amount of vitamins and minerals in food as it is actually eaten. This is because food-composition tables usually refer to fresh, raw food and do not take account of losses likely to occur during transportation, storage, and household preparation.

Fortunately in the production and marketing of food more and more attention is being given to nutritive value. The newer speedy forms of transportation are one means of helping to conserve the vitamin content of perishable foods. Modern refrigeration is proving to be another, both while food is in commercial channels and after it comes into the home. But the savings in nutritive content resulting from these improvements may be quickly lost in the home kitchen if the final preparation for the table is wrongly done. Obviously, then, the food cannot make its full contribution to the health and well-being of the family.

Data on the nutritive value of raw and cooked foods have been accumulating[1] (*1*, *13*, *27*).[2] However, no comprehensive study of the cooking of common foods in family-size quantities has been reported. Therefore the study reported here was made to help answer the question: What constitutes good cooking from a nutritive standpoint?

Preliminary to investigating in detail any single food, the effect of cooking on the nutritive value of a number of commonly used foods was studied.

Usually two common methods of preparation likely to result in widely differing retention of one or more important nutrients were applied to each food. Since the effect of cooking on nutritive value may not be the same when widely different amounts of food are involved, the general plan for this study was to cook portions sufficient to provide six common-size servings. This amount of food to be cooked at one time was selected after a survey of the literature as to size of family serving commonly used.

Nutritive values were calculated in terms of both wet and dry weight for the convenience of various persons using the data. In reporting retention of vitamins and minerals the changed weight of the food caused by cooking was taken into account. Retention is an average of percentage calculated separately for each individual sample.

Included in the preliminary studies were certain vegetables, meats, poultry, breads, and cereals. In some instances, different forms of the same food, such as fresh, frozen, and dry lima beans, were compared. Following preliminary studies on 20 foods, more comprehensive studies were made of potatoes, carrots, and peas because of the wide variety of methods used in their preparation for the table.

Although losses during preparation were expected only for heat labile or oxidizable nutrients, analyses were also made of certain stable constituents for evaluating sampling procedures and retention data.

In general, the vitamins and minerals selected for study were those which were likely to be present in appreciable amounts and for which some microbiological or chemical method of assay had been published. At the time this study was initiated (1942), modifications of these methods were being developed for several vitamins. These methods had been used chiefly in analyzing relatively simple fluids rather than such complex tissues as are represented by most animal and vegetable foods.

Early in this investigation it became apparent that there would be many problems in adapting

[1] National Cooperative Project for the Conservation of the Nutritive Value of Foods. Progress Notes. 1942 to ——. [Processed.]

[2] Italic numbers in parentheses refer to Literature Cited, p. 65.

published methods of determining nutritive value. Of primary scientific importance is the development of procedures for sampling foods by which valid comparisons of raw and cooked values can be made. The standardization of cooking conditions is also essential. Only in this way is it possible to obtain replications of a given method of preparation comparable in "doneness" of food and in ratio of weight of food to water before and after cooking.

Since the solving of many of these problems is a contribution to scientific knowledge quite as important as the findings concerning retention of nutrients, the plan of work was subsequently modified to include development of new procedures and adaptations of existing methods.

PRELIMINARY STUDIES ON 20 COMMON FOODS

The foods selected for the study of 20 common foods were such as any homemaker might serve on the family table—vegetables, meats, poultry, breads, and cereals. Table 2 includes the source and description of these foods, together with the cooking methods used.

Preparation, Cooking, Sampling

Methods of preparation and cooking in general home use were employed. To permit valid comparisons of the changes occurring in the nutritive values of foods during cooking, all cooking procedures were standardized in preliminary experiments with respect to the following: (1) Ratio of weight of raw food to cooking water; (2) rate and time of cooking; and (3) method of draining the cooked food and cooling both food and residual liquid.

The end point of most of the cooking processes was determined by puncture tests measuring a prescribed degree of doneness. In a few cases the end point was a cooking time in common usage. Palatability of the cooked vegetables as judged by three food specialists served as one of the measures of the reproducibility of the cooking procedures. By these means replications of a given cooking method were made possible.

Except in a few cases, the number of servings included in each cooked portion was six. Bread and rolls were baked in larger quantities as is common practice when cooking for a family.

Utensils were of the type used in many homes in this country. They included enameled pans with lids for boiling on top of the stove; aluminum pans for baking; aluminum skillets for braising and frying; cast aluminum Dutch ovens for pot roasting; crocks for the long baking, and uncovered glass casseroles for short baking of dry beans and peas. Knives used were of stainless steel.

All top-of-stove cooking utilized gas as the source of heat; and biscuits, bread, and rolls were baked in gas ovens. Dry beans and peas, green peppers, and sweetpotatoes were baked in electric ovens.

Since the laboratory tap water contained large quantities of copper, iron, and other minerals which affected the palatability of the cooked foods as well as certain of the chemical analyses, distilled water was used for all cooking. Vegetables were washed in tap water with a final rinse in distilled water. Meats were wiped off with a cloth wrung out of distilled water.

As a standardized procedure the distilled water used in boiling vegetables and cereals was boiled for 3 minutes before the food was added. The weight of water was adjusted to the original weight with additional boiled water before the food was added.

No salt or other seasonings were used with any of the foods except the breads. In order that the cooked products should be weighed at the same temperature (77° F.), and that hot foods should be cooled as speedily as possible for weighing and delivery to the chemical laboratory, special treatment was employed. Whenever foods were to be drained, they were drained before cooling and food and cooking liquid were cooled separately. Food in enameled pans and liquids drained into beakers or into pans were

placed in crushed ice. Food in aluminum pans was cooled at room temperature and if necessary the pans were later placed in water.

Every precaution was taken to ensure that samples of the raw and cooked products, and subsamples therefrom were truly representative of the entire mass of food, since the analyses can be no more representative than the samples. A description is included here of the way the samples were obtained from the foods in each group.

Vegetables

Since most vegetables are cooked in water, boiling was one of the cooking methods chosen for study. This was varied by using different volumes of water and cooking for long and short times as indicated in table 2. Whenever necessary, the rate of boiling was controlled to prevent excessive evaporation of liquid so the food would not cook dry.

In some cases boiling was compared with baking, as for sweetpotatoes, dry beans and peas. When dry beans and peas were soaked, the soaking water was used in the cooking. Likewise, for the peppers, part of the water used for parboiling was included when they were baked.

The boiled vegetables, upon removal from the stove, were drained for 1 minute in an enameled colander in the following way: The colander was held 20 seconds horizontally, 20 seconds at a 45° angle in one direction, and 20 seconds at a 45° angle in the opposite direction. Then the vegetables were cooled for weighing as described.

In addition to the details given in table 2, methods of preparation and sampling were as follows:

Beans and peas.—Fresh shelled lima beans were thoroughly mixed and withdrawn by scoopfuls from various parts of the lot. They were placed on enameled trays for the raw and the two cooked samples. Similarly, spoonfuls were taken for subsampling for analysis of the various nutrients.

When the packages of frozen lima beans were opened, the unthawed beans were mixed in one lot and sampling carried out as for the fresh.

Snap beans were mixed and samples withdrawn for the raw and cooked portions. Subsampling for analyses of the raw was carried out on the whole beans. Tips and strings were then removed and the beans cut into 1-inch pieces. As the beans were cut, pieces from different parts of each pod in turn were put into macroblendors containing the extractant. In this way the cutting of the raw beans was made the last operation so as to reduce losses from the cut ends caused by such factors as oxidation, evaporation, and flow of juices. Subsampling for the analyses of the cooked beans was carried out on the pieces.

In the case of dry beans and peas, several packages were thoroughly mixed on a tray and divided into three equal portions for the uncooked sample and for the two cooking methods. The uncooked dry beans or peas were ground; the resulting dry powder was mixed thoroughly and divided for analysis of the different nutrients. The baked beans or peas were similarly ground. Any liquid remaining after the baking was added and mixed thoroughly with the ground portion. The mixture was sampled by taking spoonfuls from various parts of the tray.

Cabbage.—After the outer leaves of cabbage and most of the core were removed, the heads were divided into three wedges, each representative of the entire head from top to base. One wedge was used as the raw sample, and the other two for cooking. In this way all heads were represented in all the samples. The wedges were cut into strips 1 inch wide before cooking. The drained strips from each cooking method were quickly mixed and sampled.

Corn.—The kernels of fresh corn had been machine-stripped from the cob before delivery to the laboratory. Some loss of milk from the kernels occurred during this time. Fifteen batches of corn for each of the two cooking methods were necessary since the vitamin A value and thiamine were determined by bioassay. Sampling was carried out by withdrawing spoonfuls of the kernels spread on trays. The raw and cooked samples for these assays were divided into portions which were wrapped in wax paper, packed in cardboard containers, and stored in a "dry ice" chest at —40° F. The packages were removed as needed for assaying.

Peppers.—Green peppers were cooked whole and in thirds. The whole peppers represented the shell complete except for a small section at the stem end which was cut out to permit removal of core and seeds. Although in home cooking some type of stuffing is generally used, the pepper samples for this experiment were cooked without such addition. Both whole peppers and thirds were parboiled, then baked. Thirds were also baked without parboiling. An opportunity was thus afforded for comparing not only the effectiveness of the preparation methods in retaining nutrients but also the effectiveness of two methods of sampling.

Twelve whole peppers were withdrawn at random from the lot purchased; six were used for the raw sample and six were baked whole. For analysis, the peppers were divided longitudinally so that each pepper was equally represented in the sample for each nutrient.

Eighteen peppers were similarly selected from the lot for cooking in thirds. Each raw pepper was divided longitudinally into thirds, one third being placed in each of three trays for the raw sample and the two to be cooked. The raw sample was further subdivided so that the sample for analysis of each nutrient included representative longitudinal pieces of all the 18 peppers. The cooked pieces were sliced longitudinally to eliminate as much as possible differences between the edges and the inner portion; center and outer slices in the proportion of 1 to 2 were included in the samples for each nutrient.

Rutabagas.—After being pared, the rutabagas were cut longitudinally into halves, which were further cut into thirds. The three batches, one for the raw sample and the two to be cooked, each received a third from the right and the left half of every rutabaga. The raw samples were subdivided longitudinally for analysis. The samples to be cooked were cut into cubes. The cubes from one cooked lot were thoroughly mixed and sampled. Those from the second cooked sample were mashed, spread evenly on a tray, and spoonfuls taken from various parts for analysis of each nutrient.

Sweetpotatoes.—For cooking whole, 18 sweetpotatoes were selected at random from the lot available and divided into three equal groups. One group was used as the raw sample and the other two for the cooked samples. Both the raw and the cooked potatoes were peeled prior to analysis, and quartered from bud to stem end. The sample for each nutrient included a quarter from each potato.

For baking in halves, six potatoes from the same lot were divided from bud to stem end. One half of each was used for analysis of the raw vegetable while the other was baked and then analyzed without the skins.

Turnips.—Three separate experiments were carried out on one lot of turnips.

In one experiment, whole turnips were taken at random to be analyzed raw and to be cooked. For the raw sample the turnips were pared and quartered longitudinally so that a quarter was included in the analysis of each nutrient. For the cooked sample, the turnips were pared, sliced raw, and boiled. Spoonfuls were withdrawn for analyses.

In the second experiment the whole turnips were divided into two portions for the raw and cooked samples. For cooking, turnips were pared, boiled whole, and then sliced. For analysis raw or cooked, they were sampled in the manner described above.

For the third experiment, the turnips were pared and divided longitudinally into thirds. One third from each turnip was included in the sample analyzed raw. The remaining thirds were sliced and boiled and then divided into two portions. One of these portions was analyzed as slices; the slices in the other were mashed and then analyzed. Sampling for analysis was carried out in the same way as in the two other experiments.

Turnip greens.—Turnip greens are difficult to sample adequately. Care was taken to include both old and young and dark and light leaves in equal amounts in the samples to be analyzed raw and cooked.

Meats and Poultry

Beef chuck, pork loin, beef liver, calf liver, pork liver, and chicken were selected for study.

In sampling and preparation, the procedure for the different foods was:

Beef.—The chuck cuts consisted of the third, fourth, and fifth ribs, numbering from the fore end. They were taken from the right and left sides of the same carcass.

For the raw sample the fourth rib and two slices of meat (¾ inch thick) cut from the outside of the third and fifth ribs were removed. The remainder of the cuts were braised as pot roast, those from the right side with added water and those from the left without added water. The meat was first browned for 30 minutes uncovered in 30 gm. of fat (hydrogenated cottonseed oil). Water, if used, was then added, the pots were covered, and the meat cooked slowly until tender when pierced with a skewer. When the meat was done, the pan drippings were drained off and cooled separately.

The right and left sides were analyzed separately. In preparation for analysis, raw or cooked, bone, fat, and gristle were removed, the meat was ground, spread on a tray, and sampled by spoonfuls. To the ground cooked meat the drippings were added and thoroughly mixed before sampling.

Chicken.—Eight stewing hens were disjointed; backs and breastbones were divided longitudinally with a saw so that halves of chickens could be paired for sampling raw and cooked.

Eight halves and four necks were taken for the raw sample. The remaining eight halves and four necks were divided into four portions for cooking by two methods—simmering and boiling, in water to cover, in enameled pans with lids. If necessary, water was added from time to time during the cooking period. When the chicken was tender, as determined by piercing with a skewer, the broth was drained off for cooling separately.

After removal of skin, fat, and bone, both raw and cooked chicken were separated into dark and light meat. Dark meat included meat from neck, back, thigh, and drumstick; light meat, that from wings and breast. Light and dark meats were ground and analyzed separately.

Liver.—Large blood vessels were removed from liver sliced approximately ½ inch thick. Skin also was removed except in the case of pork liver where the skin was too tender. Each slice was cut in thirds; one third was taken for the raw sample and each of the other two thirds for the two cooking methods used—frying and braising without added water. For each cooking method, the liver was browned in 15 gm. of fat (hydrogenated cottonseed oil). In frying, liver was turned when blood rose to the surface and cooked uncovered until the red color disappeared. Braised liver was cooked uncovered to a light brown, 5 minutes on each side, then covered and cooked until the red color disappeared.

The samples of liver were ground for analysis. For the cooked samples, the drippings were added to the meat after grinding.

Pork.—The center loin of pork was cut so that there were 12 chops ¾ inch thick alternating with 12 chops ⅜ inch thick. The ⅜ inch chops were used for the raw sample. The ¾ inch chops were taken in alternate order for the two cooking procedures—braising and frying, in their own fat. This sampling resulted in three loin and three rib chops in each portion for cooking.

In frying, chops were cooked uncovered, turned at intervals, until the red color disappeared throughout the meat. In braising, chops were cooked uncovered to a light brown, 5 minutes on each side, then covered, and cooked without added water until tender when pierced with a skewer and there was no red color.

Prior to analysis, bone, fat, and connective tissue were removed and the meat ground. Drippings from the fried samples, being practically pure fat, were not analyzed. However, the small quantity of drippings from the braised sample was included with the meat for analysis.

Breads

An ordinary yeast dough was used for the bread and rolls. The biscuits were leavened with baking powder. The individual ingredients in the amounts used appear in table 1. The variable in the baked products was the flour, namely, enriched white or whole-wheat. Standard home mixing and baking techniques were employed.

The yeast doughs were proofed in a cabinet at 86° F. Sixty-four minutes was required for the first rising of the bread dough, 70 minutes for the second, and 85 minutes for the third rising.

Table 1.—Breads: *Composition of doughs for bread, rolls, and biscuits*

Ingredients	Bread		Rolls		Biscuits	
	Grams		*Grams*		*Grams*	
Flour:						
White, enriched	954		[1]660		220	
Whole-wheat		854		[1]672		220
Milk	671		488		183	
Yeast	25		25		----	
Sugar	37.5		50		----	
Salt	18		9		6	
Fat	25		50		37.5	
Water	----		58		----	
Baking powder	----		----		12.3	
Total:						
White, enriched	1,730.5		1,340		458.8	
Whole-wheat		1,630.5		1,352		458.8

[1] 11 gm. more flour added during kneading.

in the baking pans. For the rolls, 48 minutes was required for the first rising, 65 minutes for the second, and 55 minutes for the third rising, on the baking sheet.

The whole-wheat and enriched white flour, yeast, and milk used in making the breads were all analyzed separately. No analysis was made of the baking powder or shortening. The baked rolls and biscuits were sampled by quartering; one-fourth of the total baked material representing every roll or biscuit was included in the analysis for each nutrient studied.

The loaves of bread were cut in eight equal parts by means of one longitudinal, one horizontal, and two diagonal cuts. Thus each half loaf consisted of four triangular pieces.

Cereals

The cereals were all sampled in the same way. Two 2-pound packages of each were thoroughly mixed. For analyses of the uncooked cereal a 350-gm. sample was taken, and four 183-gm. samples were used for cooking.

The samples of dry rolled oats were gradually added to the rapidly boiling unsalted water and were cooked either 30 minutes in a double boiler or 2½ in a saucepan over an open flame.

Boiling water was poured over the corn meal mixed with cold water. The corn meal was cooked either 60 minutes in a double boiler or 15 in a saucepan over an open flame.

The cooked cereals were well stirred, poured out on a tray, and sampled by removing spoonfuls from various parts.

Methods of Analysis for 20 Foods

The foods were analyzed immediately after sampling. For chemical and microbiological analyses of the vitamins, several extracts were made for each given sample. This permitted most of the foods to be analyzed in triplicate or quadruplicate. In general, the analytical methods were the same as those used in two previously reported studies (*56*, *57*).

Vitamins

Chemical methods were employed for the determination of ascorbic acid, carotene, and thiamine. Rat growth bioassays were used for the determination of vitamin A value (*68*) for corn and yellow corn meal and of thiamine (*12*) for corn. Nicotinic acid was determined by microbiological method. For riboflavin either chemical or microbiological methods were used.

Microbiological

Beans, lima, fresh
Cabbage, green, fall
Cabbage, white, fall
Corn meal, white and yellow
Oats, rolled
Pork
Rutabagas
Sweetpotatoes
Turnip greens
Turnips

Chemical

Beans, lima, frozen and dry
Beans, navy, dry (see appendix)
Beef
Biscuits, white and whole-wheat
Bread, white and whole-wheat
Cabbage, green, spring
Chicken
Flour, white and whole-wheat
Liver, beef, calf and pork
Milk
Peas, dry
Rolls, white and whole-wheat
Yeast

For all vitamin determinations except those on ascorbic acid, standard curves of reference prepared from pure vitamin solutions were employed. Internal standards were used as a further control for calculations and estimation of recoveries.

Ascorbic acid.—Ascorbic acid was measured by the visual titration procedures devised by Bessey and King (*11*) and Bessey (*10*). The precautions suggested by Harris and Olliver were included (*33*). Raw and cooked samples were extracted in an atmosphere of carbon dioxide. Any doubtful end point caused by turbidity or deep pigmentation was checked by the potentiometric method of Harris, Mapson, and Wang (*32*).

Carotene.—Carotene was determined by a procedure based on a combination of the methods of Wiseman and others (*71*); Moore (*53, 54*); and Moore and Ely (*55*). Either magnesium oxide with or without hyflosupercel in different concentrations or dicalcium phosphate, depending on the vegetable analyzed, were used as adsorbents in chromatographing.

Because of the varying sizes and color of the leaves in turnip greens and cabbage, the carotene was distributed quite unevenly. In such cases, as many as eight blendors were required to make allowances for the inhomogeneity of the sample.

The carotene content was measured by means of the Model 10-S Coleman Spectrophotometer using a 5-mu slit. The instrument was standardized with pure beta-carotene dissolved in Skellysolve F, the solvent used as the extractant and diluent in making up the final solutions.

Nicotinic acid.—Nicotinic acid was assayed microbiologically by the method of Snell and Wright (*65*) modified by the addition of p-aminobenzoic acid to the media as recommended by Isbell (*37*). The vitamin-B-free casein prepared in this laboratory for the biological assay of the B-vitamins was used in making the acid-hydrolyzed casein (*12*). Even with this modification, discrepancies were observed similar to those reported by other workers (*3, 16, 67*).

Riboflavin.—Riboflavin was determined microbiologically by the method of Snell and Strong (*64*), or by a chemical procedure based on the method of Hodson and Norris (*35*) modified by the adsorption technique of Ferrebee (*26*).

All samples were autoclaved with 0.15 N sulfuric acid, after digestion with pepsin and then takadiastase. Enzymatic digestion was found preferable because it decreased the bulk of the material to be handled. Also, since the same solutions were sometimes used for both thiamine and riboflavin, any bound thiamine would be freed by this treatment. By employing this enzymatic technique from the beginning for all samples, extraction of riboflavin should have been complete (*61*). This technique produced clearer solutions that required less centrifuging or filtering.

Both permanganate oxidation and hydrosulfite reduction, Lunde, Kringstad, and Olsen (*49*); Hodson and Norris (*35*); Ferrebee (*26*) were frequently used to remove interfering fluorescences when they occurred. The fluorescence was measured with a Coleman fluorophotometer.

Certain discordant results were observed in microbiological assays similar to those described by Scott, Randall, and Hessel (*62*); Strong and Carpenter (*66*); Bauernfeind, Sotier, and Boruff (*8*).

Thiamine.—This vitamin was measured by the thiochrome method of Hennessy and Cerecedo (*34*) with the application of certain modifications.

Extractions were carried out as recommended by Conner and Straub (*18*). A combination of pepsin and takadiastase or, in some instances, mylase was employed for digestion of the food instead of clarase. The digests were kept in an incubator at 37° C. for 4 hours with mylase or overnight with pepsin and takadiastase.

Because of interference from copper present in considerable quantities in the laboratory water supply, decalso could not be employed as an adsorption agent. Instead, superfiltrol was used in bottles (see Appendix C, p. 74) for the adsorption of the thiamine and the thiochrome reaction carried out directly on the adsorbent. This resulted in excellent recovery of added thiamine. It was a modification of the methods

of Emmett, Peacock, and Brown (*25*) and of Westenbrink and Goudsmit (*70*).

Superfiltrol, like decalso, made it possible to concentrate thiamine in cases of foods of low content. However, if interfering substances were also adsorbed on superfiltrol, they were usually eluted by the sodium hydroxide used in the thiochrome reaction. Other reagents commonly employed in eluting the various B-vitamins proved ineffective in separating thiamine from superfiltrol.

Fluorescence was measured with a Pfaltz and Bauer or a Lumetron fluorophotometer standardized against quinine sulfate.

Moisture.—Moisture content was determined by modification of the Association of Official Agricultural Chemists (*6*) method as developed in this laboratory. Approximately 20 to 25 gm. of each sample was placed in weighed aluminum moisture dishes, covered, then weighed on the analytical balance, and put into an air oven at 60° to 70° C. overnight. In the morning they were removed to a desiccator, cooled, weighed, and dried at 100° C. for 1 hour, after which they were again put into a desiccator, cooled, and weighed. This step was repeated at hourly intervals until constant weight was obtained. For the foods studied, with the exception of sweetpotatoes, a difference of 0.003 to 0.005 gm. was considered constant weight. For sweetpotatoes a loss of 0.01 gm. was considered constant weight because preliminary experiments indicated that the carbohydrate loss at the 100° C. temperature, averaged about 0.01 gm. per hour.

Minerals

Ash.—Ash content was measured by a modification of the A.O.A.C. (*6*) procedure. After withdrawing the sample for moisture analysis, aliquots of the food were placed on large watch glasses and dried at 60° C. in an air oven containing a circulating fan. The samples were then ground in a glass mortar and pestle to avoid iron contamination. Because the food absorbed some moisture from the air during grinding and also because the last traces of moisture were not removed in the first drying process, the samples were subjected to further drying. Two 5-gm. samples of the ground dried food were transferred quantitatively to weighed crucibles and ashed in a muffle furnace at 500° to 600° C. usually to a white ash. When the iron content of the foods was high the ash was brown in color. The ashes were then cooled and weighed.

Calcium.—The ash samples described above were used for the calcium analyses. They were treated with concentrated hydrochloric acid to precipitate out the silica and then filtered. Residue was washed thoroughly with hot distilled water. The filtrates were made up to a volume of 100 to 250 ml., depending on the size of the sample and the type of food. Calcium was then determined on aliquots by the standard macro-calcium oxalate-permanganate titration method (A.O.A.C., *6*).

Phosphorus and iron.—For phosphorus and iron, separate samples of the food were weighed, treated with magnesium nitrate and ashed as above. Phosphorus was determined by the macrovolumetric molybdate method (A.O.A.C., *6*), and iron by the ortho-phenanthroline method (Cowling and Benne, *20*). In a few cases, for comparison, iron was measured by the potassium thiocyanate method (A.O.A.C., *6*). Special care was observed throughout the analyses to prevent iron contamination. The ortho-phenanthroline method gave more satisfactory results when the photoelectric colorimeter (Klett-Summerson) was used.

Reproducibility of Procedures

The degree of reproducibility of cooking and analytical procedures was demonstrated in the case of dry lima beans, dry navy beans, and rolls. The two studies of navy beans were carried out 6 weeks apart; both the content and retention values obtained in these analyses showed close agreement. Duplicate cooked portions of the lima beans and rolls showed similar agreement in values.

Analytical results also showed a high degree of reproducibility for raw green peppers, turnips, and sweetpotatoes where there were differences in sampling procedures. Raw peppers and turnips sampled in two different ways, namely, whole and in thirds, and raw sweet-

potatoes analyzed whole and in halves gave comparable values.

Method of Calculating Retention Values

Unless the change in weight which occurs during the cooking of food is taken into account, misleading figures for the retention of nutrients may result. This is because the cooked food tends either to lose or take on water. Loss of water, as in baking, results in concentration of the food material so that the nutritive values per 100 gm. of cooked food may be greater than those for the raw sample. This makes it appear that retention is greater than 100 percent. However, if total weight and nutritive value before and after cooking are taken into account, it is possible to demonstrate the actual changes in nutritive value occurring during cooking.

In all experiments, retention of nutrients in the cooked foods was calculated as a percentage based on the nutrient content of the observed weight of the cooked food in relation to the content and weight of the original raw food. The formula for these calculations is as follows:

a = content per gm. (raw)
b = content per gm. (cooked)
Percent retention =

$$\frac{b \times \text{cooked weight (gm.)} \times 100}{a \times \text{raw weight (gm.)}}$$

By using this formula, the same percentage retention will be obtained whether the results are figured on wet or dry basis.

Results on 20 Foods

Table 3 records the vitamin and mineral content per 100 gm. dry weight of the fresh and cooked foods as well as the percent of each nutrient retained by the different cooking procedures. Table 4 gives content on the wet-weight basis. The analyses do not include residual cooking liquid except as noted.

Values for moisture, ascorbic acid, carotene, nicotinic acid, riboflavin, thiamine, ash, calcium, phosphorus, and iron content are included.

Some difficulties in evaluating the effect of cooking on the nutritive value of foods were encountered because of the lack of an objective standard for testing the accuracy of sampling and of chemical analysis.

It was found that retention of ash and of nicotinic acid in the cooked foods plus residual liquid served as a check on all procedures. Retention of significantly more or less than 100 percent of a heat-stable nutrient indicated that the method of analysis, rather than of sampling, should be questioned.

When all the heat-stable nutrients were out of line, the sampling method was probably inadequate and subsamples differed significantly in their content of the nutrients analyzed. In such cases, the results for heat-labile nutrients should be viewed with suspicion.

On the whole, the results of these studies indicated successful sampling and analyses. Exceptions were fried and baked products and cooked cereals. In the latter the difficulty appeared to be formation of a crust or scum which adhered to the sides and bottom of the utensils and which made quantitative transfer and adequate mixing of the sample extremely difficult. This experience, as well as that reported by Grindley and co-workers (*28*, *29*, *30*) for protein, ash, and fat values in meats and by McCance, Widdowson, and Shackleton (*50*) in studies of mineral composition of foods, shows the importance of taking into consideration any possible mechanical losses in evaluating the effect of cooking on nutritive value.

Ascorbic Acid

Among the raw foods highest in ascorbic acid were green peppers containing about 2,000 mg. per 100 gm. dry weight. Turnip greens containing about 840 mg., green cabbage 750 mg., and white cabbage 470 mg. per 100 gm. dry weight ranked next. Raw rutabagas and turnips ranked about the same with 300 mg. of ascorbic acid per 100 gm. dry weight.

Ascorbic acid was found to be the most sensitive of all the vitamins studied. For the most part, retention of this vitamin in this series of cooked foods ranged from 30 to 50 percent, with extremes as low as 18 percent for cabbage strips and as high as 100 percent for sweetpotatoes boiled whole unpared.

In general, the greater the volume of cooking water employed, or the longer the time of cooking, or the smaller the piece, the less ascorbic acid was retained. For example, fresh lima beans cooked in water to cover retained 23 percent of their ascorbic acid, whereas beans cooked in half as much water retained 38 percent. Wax beans boiled in water to cover for 2 hours retained 35 percent ascorbic acid; those cooked in the same quantity of water 20 minutes retained 54 percent.

Size of piece governs length of time required to cook to a desired stage of doneness. Size of piece may also govern the amount of leaching or destruction of ascorbic acid. For example, the lowest retention of all occurred in cabbage cut into strips 1 inch wide and boiled for 1 hour. Only 18 percent of its original vitamin C was retained.

Sweetpotatoes cut in half before being baked retained 31 percent of their ascorbic acid; those baked whole retained 89 percent. Turnips pared and cooked whole retained 49 percent of their ascorbic acid, but when cooked sliced in half the time retained 61 percent. Doubtless other factors such as temperature during cooking, and kind, variety, and chemical composition of the food affect these results and call for further investigation.

Carotene

Among the raw foods used in this study turnip greens were the richest source of carotene, containing approximately 43 mg. per 100 gm. dry weight. Sweetpotatoes were intermediate, whereas dry mature peas were lowest among the foods analyzed.

Carotene was the most stable vitamin. In nearly every case, practically 100 percent of the carotene was retained in the cooked vegetable regardless of method of preparation or cooking.

Exceptions to complete retention of carotene were the frozen lima beans, dry peas, and cabbage. Boiling the frozen lima beans in a small amount of water resulted in 86-percent retention of carotene, while doubling the volume of cooking water gave only 78-percent retention. This lower retention may have been due to the damage to the tissues in processing, so that in cooking the carotene passed into the cooking water. Similarly, the boiled dry peas showed an average carotene retention of only 85 percent; again, the break-down of tissue during cooking may have been the cause.

The lowest retention of carotene occurred in cabbage. Cooked, green fall cabbage retained 33 percent and green spring cabbage 67 percent. This low retention may have been due to dispersion from the cabbage strips, to unequal distribution of carotene in the leaves, or to oxidative enzyme destruction prior to cooking.

Nicotinic Acid

Raw beef liver contained about 70 mg. of nicotinic acid, pork liver 65 mg., and calf liver 36 mg. per 100 gm. dry weight. Pork loin and beef contained 14 mg. per 100 gm. Whole-wheat bread and rolls gave values near 5 mg., dry beans near 2 mg. of nicotinic acid per 100 gm. Whole-wheat bread and rolls contained about twice as much of this vitamin as did the enriched white products.

In general, most of the nicotinic acid was retained in the baked products and in those foods where all of the cooking liquid was included in the analysis. Contrary to expectations, pork loin fried or braised as chops, retained only about 70 to 80 percent of its nicotinic acid. When water was used in the cooking and not included in the analysis, as for chicken, retention was considerably lower, about 30 percent. About 70 percent of the nicotinic acid was found in the broth.

Riboflavin

Of the 20 foods, beef and calf liver were highest in riboflavin, with 3 to 16 mg. per 100 gm. dry weight of the fresh food. Dry beans and peas, corn meal, rolled oats, whole-wheat bread, and whole-wheat flour contained between 0.4 to 1.0 mg. per 100 gm.; whereas the other foods contained less.

Riboflavin is another vitamin that seems to be stable to heat. In general, the baked and fried foods and the cereals retained 100 percent of their initial riboflavin. Boiled vegetables retained 60 to 90 percent and the retention did not

appear to be influenced much by varying the volume of water or cooking time. Simmered chicken retained 70 percent and boiled chicken 55 percent of the original riboflavin present. The rest was accounted for in the broth.

Thiamine

Among the foods studied, pork loin was the richest source of thiamine. It contained 2 mg. per 100 gm. dry weight and retained 60 to 70 percent during cooking. Dry peas and beans ranked next. They contained approximately 0.7 mg. per 100 gm. dry weight uncooked and retained 40 to 80 percent when baked.

Thiamine, being both soluble in water and heat labile, was only partially retained in most of the cooked foods. Retention ranged from 35 to 100 percent, but usually was above 60 percent. In certain cases, the more water used for cooking, the lower was the retention in the cooked food. This is seen in the fresh lima beans where about a third more thiamine was retained in the beans cooked in a small quantity of water than in those cooked in double the volume of water.

Minerals

Turnip greens ranked highest in calcium; they contained 3,500 mg. per 100 gm. on a dry-weight basis. Liver was a rich source of phosphorus, with 1,300 mg. per 100 gm. dry weight. Rich sources of iron were pork and beef livers, with approximately 80 and 40 mg. per 100 gm. of uncooked food. Turnip greens contained 33 mg. per 100 gm. Whole-wheat flour contained over twice as much calcium, phosphorus, iron, and ash as the enriched white flour.

In foods cooked in water, mineral retention ranged from 50 to 100 percent. In general, the more water used in cooking, the lower was the mineral retention in the drained food.

Sweetpotatoes, boiled whole unpared, retained 100 percent of their ash. On the other hand, ash retention was low in cabbage cut in strips before cooking. Of the foods studied, chicken, either boiled or simmered, showed the lowest mineral retention; the phosphorus and ash amounted to only about 50 percent. These nutrients, however, appeared in the chicken broth.

Summary and Conclusions on 20 Foods

For this study 20 foods typical of those a homemaker might choose for family use were purchased on the Washington, D. C., market. They included vegetables, meats, poultry, flour, and cereals. Household methods of preparation and cooking were used, such as boiling, baking, simmering, braising, pot roasting, and frying. Reproducible methods for sampling, cooking, and analysis were developed and standardized to make possible valid comparison of the nutritive value of raw and cooked food.

For calculating true vitamin and mineral retention, a formula was devised that takes account of loss or gain of water and solids in the cooked products. By means of this formula, the calculated retention was the same whether on the basis of wet or dry weight of food.

Content of selected nutrients in the raw and cooked foods was determined and retention computed. In choosing the nutrients to be studied, both the distribution in the raw food and the destructibility of the nutrient were taken into consideration. Whenever possible, ascorbic acid and thiamine were studied because they are most sensitive to food preparation treatment. Minerals and the three heat-stable vitamins—carotene, nicotinic acid, and riboflavin—were studied even when no changes were expected. Their complete retention served as evidence that sampling procedures were satisfactory and that observed retention of the more easily destroyed vitamins was correct.

In general, the results demonstrate that with all the preparation methods used, the cooked foods retain less of their original ascorbic acid and thiamine than nicotinic acid, riboflavin, carotene, and minerals. Although the results in this preliminary study are based on a small number of samples for each food, taken together they show consistent trends for any one cooking method.

Boiling.—Boiling appears to be the cooking method most destructive of ascorbic acid and thiamine. Retention of these nutrients decreased with longer cooking time, larger quantity of cooking water, and the smaller size of the pieces cooked. Mashing after boiling, being an

additional treatment, resulted in further small losses of ascorbic acid.

Carotene was retained with very little loss, except in frozen lima beans and cut cabbage. In these two foods significant losses may have been due to breaking off and suspension of small particles of vegetable material in the cooking liquid or to chemical changes in the tissues.

Nicotinic acid retention was 100 percent when the cooking liquid was included in the analysis, but considerably less in the drained food. The cooking time made no difference in the amount of the nutrient retained. An increased volume of cooking water resulted in somewhat higher losses.

Riboflavin and mineral retention followed much the same pattern as retention of nicotinic acid.

Baking.—Green peppers and sweetpotatoes were the only fresh vegetables subjected to baking. Ascorbic acid retention was excellent in the peppers and whole sweetpotatoes, but the sweetpotatoes halved before baking retained less than one-third of the original ascorbic acid. Retention of calcium, phosphorus, and iron was high, as would be expected.

Thiamine was retained to the extent of about 80 percent in the biscuits and 65 percent in the bread, both made with enriched white flour. In corresponding products made with whole-wheat flour, about 90 percent of this vitamin was retained.

Dry lima and navy beans baked after soaking and boiling retained over 50 percent of their thiamine. Retention was even higher for nicotinic acid. No changes were observed in riboflavin and the minerals.

Simmering.—Simmered chicken retained over 15 percent more riboflavin than did boiled chicken. In both simmered and boiled chicken, about 30 percent nicotinic acid, 70 percent iron, and 50 percent phosphorus were retained. The remainder of these nutrients was found in the broth.

Braising.—In the three kinds of liver studied —beef, calf, and pork—more than 50 percent thiamine and 85 percent or more riboflavin were retained. Except for nicotinic acid in pork liver, the other nutrients remained unchanged.

Pot roasting.—Beef chuck after pot roasting retained completely its original nicotinic acid, riboflavin, and minerals when drippings were included.

Frying.—After frying, the three kinds of liver retained 75 percent or more of their thiamine. The remaining nutrients studied were unaffected by this method of cooking.

Table 2.—20 Common Foods: ***Preparation, home cooking procedures, yield of product, residual liquid, and description of raw sample***

Food and cooking method	Identification No.[1]	Number of samples	Average size of raw sample (edible portion)	Water used in cooking	Average cooking time	Average cooked yield	Residual cooking liquid	Description of raw sample
			Gm.	*Ml.*	*Min.*	*Gm.*	*Ml.*	
Beans:								
Lima:								
Fresh, raw, Henderson variety:								From Maryland Agricultural Experiment Station, College Park, Md., Sept. 1942, machine-shelled, delivered within 4 hr. of picking; held overnight at 40° F.
Boiled covered	2	3	504	238	30	484	48	
Boiled covered	3	3	504	474	30	480	306	
Frozen, raw:								
Boiled unthawed, covered	5	3	566	266	16	639	26	From Washington, D. C., May 1943, frozen commercially.
Boiled unthawed, covered	6	3	566	532	16	670	300	
Dry, raw:								
Boiled covered, after soaking 16 hr.	8	2	422	[2]1,200	82	1,160	204	From California, April 1943, stored in cupboard 2 to 15 days at room temperature.
Boiled covered, after soaking 16 hr., Then baked uncovered at 350° F.	9	2	422	[2]1,200	77	-------	-------	
				-------	30	1,100	152	
Navy:								
Dry, raw:								
Boiled covered, after soaking 16 hr., Then baked covered at 250° F.	11	2	452	[3]1,660	30	-------	-------	From Michigan, March 1943, stored in cupboard 4 to 45 days at room temperature.
				-------	360	1,378	105	
Boiled covered, after soaking 16 hr., Then baked uncovered at 350° F.	12	2	452	[4]1,285	120	-------	-------	
				-------	30	1,145	118	
Snap:								
Raw, Bountiful variety:								From Bur. Plant Indus., Soils, and Agr. Engin., Beltsville, Md., July 1942, delivered freshly picked from fields; held overnight at 40°F.
Boiled covered, 1-in. pieces	14	3	500	439	25	476	288	
Boiled covered, 1-in. pieces	15	3	570	500	120	541	335	
Wax:								
Raw, Pencil Pod variety:								From Bur. Plant Indus., Soils, and Agr. Engin., Beltsville, Md., Aug. 1942, delivered freshly picked from fields; held overnight at 40° F.
Boiled covered, 1-in. pieces	17	1	602	464	31	592	191	
Boiled covered, 1-in. pieces	18	1	602	464	120	547	165	
Beef:								
Chuck, raw:								U. S. Choice-grade, beef-type steer, from Bur. Animal Indus., Beltsville, Md., Jan. 1943. Held at 34° F. for 19 days after slaughter; then held at 40° F. for 3 days.
Pot roast, braised, no water	20	2	[5]1,850	0	222	[5]1,143	[6]172	
Pot roast, braised, water added	22	2	[5]1,840	354	244	[5]1,199	[6]636	
Biscuits:								
White, enriched:								Ingredients purchased Washington, D. C., April 1943.
Baked at 425° F.	24	3	320	-------	14	238	-------	
Whole-wheat:								
Baked at 425° F.	26	3	345	-------	14	256	-------	
Bread:								
White, enriched:								Ingredients purchased Washington, D. C., May 1943.
Baked at 375° F.	28	1 (3 loaves)	1,500	-------	40	1,258	-------	
Whole-wheat:								
Baked at 375° F.	30	1 (3 loaves)	1,500	-------	40	1,285	-------	

See footnotes at end of table.

Table 2.—20 Common Foods: *Preparation, home cooking procedures, yield of product, residual liquid, and description of raw sample*—continued

Food and cooking method	Identification No. [1]	Number of samples	Average size of raw sample (edible portion)	Water used in cooking	Average cooking time	Average cooked yield	Residual cooking liquid	Description of raw sample
			Gm.	*Ml.*	*Min.*	*Gm.*	*Ml.*	
Cabbage:								
Green, raw:								
Boiled uncovered, strips 1-in. wide	32	9	585	1,215	10	573	984	From Washington, D. C., Oct. 1942 and May 1943, held overnight at 40° F.
Boiled uncovered, strips 1-in. wide	33	9	606	1,260	60	567	739	
White, raw:								
Boiled uncovered, strips 1-in. wide	35	5	580	1,207	10	580	900	From Washington, D. C., Oct. 1942, held overnight at 40° F.
Boiled uncovered, strips 1-in. wide	36	6	573	1,191	60	525	528	
Chicken:								
Raw, Rhode Island Red:								
Simmered disjointed, covered	38; 38a and b	2	[7]1,665	[8]1,893	240	[7]1,014	2,080	2-year-old hens from Bur. Animal Indus., Beltsville, Md., Jan. 1943; held at 40° F. for 4 days after killing.
Boiled disjointed, covered	39; 39a and b	2	[7]1,560	[8]1,893	194	[7]1,012	981	
Corn:								
Raw, Golden Bantam variety:								
Boiled covered	41	15	645	291	10	646	187	From Maryland Agricultural Experiment Station, College Park, Md., Aug. 1942, kernels machine-stripped from cob.
Boiled covered	42	15	643	581	30	655	327	
Corn meal:								
White, raw:								
Cooked in double boiler	44	2	183	1,176	60	1,315	------	From Washington, D. C., Nov. 1942, degerminated, packaged.
Cooked in saucepan	45	2	183	1,176	15	1,305	------	
Yellow, raw:								
Cooked in double boiler	47	2	183	1,176	60	1,267	------	
Cooked in saucepan	48	2	183	1,176	15	1,282	------	
Liver:								
Beef, raw:								
Fried	52	1	592	------	13	402	[6]14	From Washington, D. C., Dec. 1942, held 2 days at 32° F.
Braised	53	1	682	------	15	416	[6]18	
Calf, raw:								
Fried	55	1	624	------	19	[6]436	------	From Washington, D. C., Jan. 1943, held overnight at 40° F.
Braised	56	1	627	------	11½	[6]490	------	
Pork, raw:								From hogs fed well-balanced fattening ration and weighing about 225 lb., Bur. Animal Indus., Beltsville, Md., Feb. 1943. Held at 18° F. for 18 days after slaughter, then held at 32° F. for 2 days.
Fried	58	1	[9]659	------	16	[6 9]495	------	
Braised	59	1	[9]669	------	12	[6 9]524	------	
Oats, rolled:								
Raw:								
Cooked in double boiler, first adding oats to rapidly boiling water.	64	2	183	940	30	1,056	------	From Washington, D. C., Nov. 1942, quick-cooking, packaged.
Cooked in saucepan	65	2	183	940	2½	1,078	------	

Peas:								
Dry:								
Raw, Alaska variety:								
Boiled covered, after soaking 16 hr	67	2	349	[10]1,050	70	943	171	Mature green peas from Idaho, March 1943, stored in cupboard 2 weeks at room temperature.
Boiled covered, after soaking 16 hr., Then baked uncovered at 350° F	68	2	349	[11]1,000	70			
					30	967		
Raw, Profusion variety:								
Boiled covered, after soaking 16⅓ hr	70	2	349	[12]1,500	140	950	48	Mature peas of cream and green color from Oregon, March 1943, stored in cupboard 1 month at room temperature.
Boiled covered, after soaking 16⅓ hr., Then baked uncovered at 350° F	71	2	349	[13]1,450	140			
					30	882	51	
Peppers:								
Green, raw:								
Parboiled whole,	73	1	574	2,000	5	593	1,780	From Washington, D. C., Oct. 1942, held overnight at 40° F.
Then baked		1	[14]593	177	40	490	44	
Baked in thirds	75	1	632	177	60	407	25	
Parboiled in thirds,	76	1	644	2,000	5	637	1,670	
Then baked		1	[14]637	118	40	458	36	
Pork:								
Loin chops, raw:								
Fried	78	1	[5]902		15	[5]616		From Washington, D. C., Nov. 1942, held 3 days at 34° F.
Braised	79	1	[5]887		30	[5]612		
Rolls:								
White, enriched:								Ingredients purchased Washington, D. C., April 1943.
Baked at 425° F	81,82	2	1,252		14	967		
Whole-wheat:								
Baked at 425° F	84,85	2	1,247		14	1,019		
Rutabagas:								
Raw:								
Boiled cubed, uncovered	87	2	893	1,032	22½	814	537	From Washington, D. C., Oct. 1942, held overnight at 40° F.
Boiled cubed, uncovered	88	2	903	1,038	22½	863	540	
Mashed			[14]863			833		
Sweetpotatoes:								
Raw:								
Boiled uncovered, whole, unpared	90	1	1,338	1,400	46	1,390	720	Deep-yellow flesh, from Georgia Agricultural Experiment Station, Experiment, Ga., Dec. 1942, held 33 days at 54° F.
Baked whole, unpared, at 425° F	91	1	1,416		65	1,140		
Baked halved, unpared, at 425° F	93	1	766		48	593		
Turnips:								
Raw, Purple Top variety:								
Boiled pared, sliced, uncovered	95	3	654	585	19½	611	184	From Washington, D. C., Oct. 1942, held overnight at 40° F.
Boiled whole, pared, uncovered, then sliced	97	2	768	1,300	40	763	618	
Boiled pared (sampled thirds), sliced, uncovered	99	2	757	677	16	718	240	
Boiled pared (sampled thirds), sliced, uncovered	100	2	822	735	16	794	326	
Mashed			[14]794			750		
Turnip greens:								
Raw:								
Boiled covered	102	1	680	1,000	13	641	600	From Washington, D. C., Oct. 1942, held overnight at 40° F.
Boiled covered	103	1	680	1,000	60	651	482	

[1] All samples raw and cooked are considered. Only those for cooked samples appear in this table.
[2] 950 ml. at start, 270 ml. added during cooking or baking.
[3] 950 ml. at start, 750 ml. added to one sample and 630 ml. to the other during baking.
[4] 950 ml. at start, 250 ml. added to one sample and 420 ml. to the other during baking.
[5] Includes skin.
[6] Includes drippings.
[7] Includes skin and bone.
[8] More water added during cooking.
[9] Includes skin.
[10] 950 ml. at start, 100 ml. added during cooking.
[11] 950 ml. at start, 100 ml. added to one sample but not to the other during cooking.
[12] 950 ml. at start, 600 ml. added to one sample and 500 ml. to the other during boiling.
[13] 950 ml. at start, 490 ml. added to one sample and 600 ml. to the other during baking.
[14] Average size of boiled sample; peppers parboiled.

Table 3.—20 Common Foods: *Vitamin and mineral content[1] per 100 grams dry weight and retention,[2] as affected by various home cooking procedures*

Food and cooking method [3]	Identification No.	Moisture [1]	Ascorbic acid		Carotene		Nicotinic acid		Riboflavin		Thiamine	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Beans:												
Lima:												
Fresh, raw, Henderson variety	1	67.6	66.9		0.396						0.756	
Boiled covered, 30 min., 0.47 ml. water per gm. food.	2	65.2	24.5	37.6	.376	93.3			0.420		.402	54.1
Boiled covered, 30 min., 0.94 ml. water per gm. food.	3	66.6	15.8	23.3	.409	100.0					.280	34.6
Frozen, raw	4	60.2	7.7		.088		1.61		1.064		.414	
Boiled unthawed, covered, 16 min., 0.47 ml. water per gm. food.	5	66.7	3.3	40.1	.081	86.4	1.61	94.2	.714	63.2	.345	78.7
Boiled unthawed, covered, 16 min., 0.94 ml. water per gm. food.	6	69.1	3.4	42.0	.075	78.5	1.25	71.1	1.014	87.5	.360	79.6
Dry, raw	7	10.1					1.99		.731		.676	
Boiled covered, 82 min., water to cover, after soaking 16 hr.	8	76.6					1.78	86.9	.611		.400	57.3
Boiled covered, 77 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	9	71.5					1.75	87.0	.515		.374	54.0
Dry, raw	7	8.2					1.75		.708		.677	
Boiled covered, 82 min., water to cover, after soaking 16 hr.	8	71.3					1.56	88.3	.703	98.7	.434	63.4
Boiled covered, 77 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	9	67.9					1.45	82.3	.654	91.7	.453	66.2
Navy:												
Dry, raw	10	7.1					2.24		.425		.629	
Boiled covered, 30 min., water to cover, after soaking 16 hr., then baked covered at 250° F., 360 min.	11	70.4					1.92	84.3	.551	127.6	.354	55.6
Boiled covered, 120 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	12	67.9					1.93	87.5	.519	123.9	.503	81.4
Dry, raw	10	6.9					2.08		.624		.688	
Boiled covered, 30 min., water to cover, after soaking 16 hr., then baked covered at 250° F., 360 min.	11	71.3					1.71	67.3	.910	119.6	.334	39.6
Boiled covered, 120 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	12	65.6					1.72	105.7	.862	177.1	.540	100.7
Snap:												
Raw, Bountiful variety	13	86.9	187.0									
Boiled covered, 1-inch pieces, 25 min., 0.88 ml. water per gm. food.	14	88.4	81.9	41.5	2.879							
Boiled covered, 1-inch pieces, 120 min., 0.88 ml. water per gm. food.	15	88.5	62.2	33.4	2.308							
Wax:												
Raw, Pencil Pod variety	16	88.0	188.3									
Boiled covered, 1-inch pieces, 31 min., 0.77 ml. water per gm. food.	17	90.0	115.0	53.6								
Boiled covered, 1-inch pieces, 120 min., 0.77 ml. water per gm. food.	18	88.1	67.7	34.9								
Beef:												
Pot roast, chuck:												
Left side, raw	19	[4]71.6					14.3		1.092			
Braised, 222 min., no water	20	[4]46.0					8.15	88.9	.796	113.8		
Right side, raw	21	[4]71.1					13.8		1.116			
Braised, 244 min., water added	22	[4]64.5					9.86	115.1	.779	106.9		

See footnotes at end of table.

Table 3.—20 Common Foods: *Vitamin and mineral content*[1] *per 100 grams dry weight and retention*,[2] *as affected by various home cooking procedures*—continued

Food and cooking method[3]	Identification No.	Moisture[1]	Ash		Calcium		Phosphorus		Iron	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Beans:										
Lima:										
Fresh, raw, Henderson variety	1	67.6	5,570		150		526		7.8	
Boiled covered, 30 min., 0.47 ml. water per gm. food.	2	65.2	4,490	78.8	130	84.8	456	85.3	7.4	92.8
Boiled covered, 30 min., 0.94 ml. water per gm. food.	3	66.6	3,920	60.6	103	58.2	461	75.5	6.9	76.2
Frozen, raw	4	60.2	3,680		74.0		461		7.3	
Boiled unthawed, covered, 16 min., 0.47 ml. water per gm. food.	5	66.7	3,600	92.8	69.9	89.1	415	84.7	7.5	97.7
Boiled unthawed, covered, 16 min., 0.94 ml. water per gm. food.	6	69.1	2,980	74.7	71.7	89.0	411	81.7	7.1	89.8
Dry, raw	7	10.1	4,910		63.0		386		9.6	
Boiled covered, 82 min., water to cover, after soaking 16 hr.	8	76.6	5,110	100.5	62.3	95.8	376	94.0	8.8	88.8
Boiled covered, 77 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	9	71.5	4,870	97.6	60.0	98.1	380	96.4	9.1	93.1
Dry, raw	7	8.2	4,870		64.9		344		9.4	
Boiled covered, 82 min., water to cover, after soaking 16 hr.	8	71.3	4,760	97.5	68.9	105.6	371	107.7	9.8	103.5
Boiled covered, 77 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	9	67.9	4,840	98.4	62.9	96.2	371	106.9	8.7	92.4
Navy:										
Dry, raw	10	7.1	3,790		183		455		8.2	
Boiled covered, 30 min., water to cover, after soaking 16 hr., then baked covered at 250° F., 360 min.	11	70.4	3,940	102.8	160	86.0	473	102.4	8.6	103.4
Boiled covered, 120 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	12	67.9	3,860	103.4	170	94.3	462	102.7	9.4	116.2
Dry, raw	10	6.9	3,720		168		437		9.1	
Boiled covered, 30 min., water to cover, after soaking 16 hr., then baked covered at 250° F., 360 min.	11	71.3	3,700	81.3	180	87.9	447	83.4	9.5	85.1
Boiled covered, 120 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	12	65.6	3,790	130.4	175	133.9	441	129.6	8.4	117.9
Snap:										
Raw, Bountiful variety	13	86.9	7,200		428		437		11.9	
Boiled covered, 1-inch pieces, 25 min., 0.88 ml. water per gm. food.	14	88.4	5,650	78.6	421	93.8	434	101.9	8.5	66.2
Boiled covered, 1-inch pieces, 120 min., 0.88 ml. water per gm. food.	15	88.5	5,120	71.8	426	100.6	385	89.1	7.5	64.5
Wax:										
Raw, Pencil Pod variety	16	88.0	7,860		433		504		7.8	
Boiled covered, 1-inch pieces, 31 min., 0.77 ml. water per gm. food.	17	90.0	7,590	84.8	477	96.7	500	87.2	8.2	92.3
Boiled covered, 1-inch pieces, 120 min., 0.77 ml. water per gm. food.	18	88.1	7,560	92.9	481	107.1	514	98.6	8.5	105.0
Beef:										
Pot roast, chuck:										
Left side, raw	19	[4]71.6	3,870				675		10.7	
Braised, 222 min., no water	20	[4]46.0	2,370	95.4			443	102.2	5.63	52.7
Right side, raw	21	[4]71.1	3,800				675		10.1	
Braised, 244 min., water added	22	[4]64.5	2,750	110.9			518	118.1	8.1	123.4

See footnotes at end of table.

Table 3.—20 Common Foods: *Vitamin and mineral content*[1] *per 100 grams dry weight and retention*,[2] *as affected by various home cooking procedures*—continued

Food and cooking method [3]	Identification No.	Moisture [1]	Ascorbic acid		Carotene		Nicotinic acid		Riboflavin		Thiamine	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Biscuits:												
White, enriched:												
Raw ingredients [5]	23											
Baked at 425° F., 14 min.	24	20.2					1.15	92.8	0.604	151.1	0.279	81.6
Whole-wheat:												
Raw ingredients [5]	25											
Baked at 425° F., 14 min.	26	16.9					2.82	75.8	.705	128.6	.297	88.8
Bread:												
White, enriched:												
Raw ingredients [5]	27											
Baked at 375° F., 40 min.	28	31.6					2.08	117.9	1.002	188.6	.268	65.9
Whole-wheat:												
Raw ingredients [5]	29											
Baked at 375° F., 40 min.	30	32.7					4.97	100.1	1.026	141.2	.385	92.5
Cabbage:												
Green, raw	31	91.9	708.6		0.314				3.640			
Boiled uncovered, 1-inch strips, 10 min., 2.08 ml. water per gm. food.	32	93.4	373.9	43.8	.123	32.5			3.030	69.0		
Boiled uncovered, 1-inch strips, 60 min., 2.08 ml. water per gm. food.	33	93.9	238.0	23.6	.154	34.5			2.213	42.7		
Green, raw	31	92.4	795.4		.440		3.13		1.717			
Boiled uncovered, 1-inch strips, 10 min., 2.08 ml. water per gm. food.	32	94.8	452.8	37.2	.459	67.6	2.23	46.4	1.274	48.0		
Boiled uncovered, 1-inch strips, 60 min., 2.08 ml. water per gm. food.	33	94.8	226.3	18.3	.463	67.5	2.15	44.2	1.346	50.8		
White, raw	34	91.3	470.1		.088							
Boiled uncovered, 1-inch strips, 10 min., 2.08 ml. water per gm. food.	35	94.0	285.0	41.8	.083	62.2						
Boiled uncovered, 1-inch strips, 60 min., 2.08 ml. water per gm. food.	36	93.5	206.2	30.0	.082	63.1						
Chicken:												
Rhode Island Red:												
Raw (dark and light meat)	37	[4]70.7					18.8		.198			
Simmered disjointed, covered, 240 min., water to cover.	38	[4]59.7					7.05	31.3	.169	71.6		
Boiled disjointed, covered, 194 min., water to cover.	39	[4]58.6					6.69	32.5	.118	54.7		
Raw (dark meat)	37a	[4]70.9					38.1		.477			
Simmered disjointed, covered, 240 min., water to cover.	38a	[4]59.1					10.2		.290			
Boiled disjointed, covered, 194 min., water to cover.	39a	[4]57.0					10.9		.223			
Raw (light meat)	37b	[4]70.5					40.5		.318			
Simmered disjointed, covered, 240 min., water to cover.	38b	[4]60.3					17.6		.355			
Boiled disjointed, covered, 194 min., water to cover.	39b	[4]60.2					17.6		.266			
Corn:												
Fresh raw, Golden Bantam variety	40	75.9	48.7		[6].483						[7].585	
Boiled covered, 10 min., 0.45 ml. water per gm. food.	41	75.7	38.6	70.3	[6].501						[7].448	77.4
Boiled covered, 30 min., 0.90 ml. water per gm. food.	42	79.8	23.9	43.5	[6].532						[7].371	54.2

See footnotes at end of table.

Table 3.—20 Common Foods: *Vitamin and mineral content*[1] *per 100 grams dry weight and retention*,[2] *as affected by various home cooking procedures*—continued

Food and cooking method [3]	Identification No.	Moisture [1]	Ash		Calcium		Phosphorus		Iron	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Biscuits:										
White, enriched:										
Raw ingredients [5]	23									
Baked at 425° F., 14 min	24	20.2	4,260		176		308		6.4	
Whole-wheat:										
Raw ingredients [5]	25									
Baked at 425° F., 14 min	26	16.9	5,260		190		505		8.0	
Bread:										
White, enriched:										
Raw ingredients [5]	27									
Baked at 375° F., 40 min	28	31.6	2,600		81.3		192		2.3	
Whole-wheat:										
Raw ingredients [5]	29									
Baked at 375° F., 40 min	30	32.7	3,490		104		464		4.6	
Cabbage:										
Green, raw	31	91.9	9,250		658		415		5.6	
Boiled uncovered, 1-inch strips, 10 min., 2.08 ml. water per gm. food.	32	93.4	6,930	62.1	623	78.5	404	80.9	5.6	84.0
Boiled uncovered, 1-inch strips, 60 min., 2.08 ml. water per gm. food.	33	93.9	6,930	52.6	638	68.1	441	74.7	5.1	63.7
Green, raw	31	92.4	8,580		566		478		4.8	
Boiled uncovered, 1-inch strips, 10 min., 2.08 ml. water per gm. food.	32	94.8	6,400	48.5	490	56.4	500	68.1	6.3	85.2
Boiled uncovered, 1-inch strips, 60 min., 2.08 ml. water per gm. food.	33	94.8	7,670	57.4	577	65.5	592	79.6	4.9	65.4
White, raw	34	91.3	8,290		732		401		3.5	
Boiled uncovered, 1-inch strips, 10 min., 2.08 ml. water per gm. food.	35	94.0	6,400	53.2	714	67.1	359	61.5	5.0	98.2
Boiled uncovered, 1-inch strips, 60 min., 2.08 ml. water per gm. food.	36	93.5	6,850	56.6	725	67.8	405	69.1	4.4	85.4
Chicken:										
Rhode Island Red:										
Raw (dark and light meat)	37	[4]70.7	1,850				362		3.5	
Simmered disjointed, covered, 240 min., water to cover.	38	[4]59.7	1,035	46.9			233	53.9	2.9	67.9
Boiled disjointed, covered, 194 min., water to cover.	39	[4]58.6	986	48.8			216	54.6	2.7	69.2
Raw (dark meat)	37a	[4]70.9	3,770				725		8.9	
Simmered disjointed, covered, 240 min., water to cover.	38a	[4]59.1	1,960				427		5.8	
Boiled disjointed, covered, 194 min., water to cover.	39a	[4]57.0	2,030				441		6.6	
Raw (light meat)	37b	[4]70.5	3,910				787		5.2	
Simmered disjointed, covered, 240 min., water to cover.	38b	[4]60.3	1,890				450		4.5	
Boiled disjointed, covered, 194 min., water to cover.	39b	[4]60.2	1,990				436		3.8	
Corn:										
Fresh raw, Golden Bantam variety	40	75.9	2,770		5.1		425		2.4	
Boiled covered, 10 min., 0.45 ml. water per gm. food.	41	75.7	2,370	79.6	6.54	123.3	368	80.1	2.1	82.0
Boiled covered, 30 min., 0.90 ml. water per gm. food.	42	79.8	2,110	67.3	6.4	109.6	352	73.2	2.0	73.7

See footnotes at end of table.

Table 3.—20 Common Foods: *Vitamin and mineral content*[1] *per 100 grams dry weight and retention,*[2] *as affected by various home cooking procedures*—continued

Food and cooking method [3]	Identification No.	Moisture [1]	Ascorbic acid		Carotene		Nicotinic acid		Riboflavin		Thiamine	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Corn meal:												
White, raw	43	9.5							0.628		0.239	
Cooked in double boiler, 60 min	44	87.6							.548	90.2	.244	105.6
Cooked in saucepan, 15 min	45	87.4							.603	96.8	.271	114.5
Yellow, raw	46	9.4			[8]0.168		1.85		.447		.168	
Cooked in double boiler, 60 min	47	87.5			[8].189		1.90	101.1	.336	72.1	.141	80.5
Cooked in saucepan, 15 min	48	87.3			[8].228		1.72	93.4			.164	95.9
Flour (used in making biscuits, bread, rolls):												
White, enriched	49	11.8					1.68		.298		.441	
Whole-wheat	50	10.4					5.27		.530		.443	
Liver:												
Beef:												
Raw	51	74.7					70.4		15.85		.597	
Fried, 13 min	52	55.4					57.8	101.8	11.96	93.4	.466	96.8
Braised, 15 min	53	52.2							11.16	84.5	.243	48.9
Calf:												
Raw	54	70.1					35.8		10.15		.783	
Fried, 19 min	55	56.4					36.7	104.5	10.17	102.1	.557	72.6
Braised, 11½ min	56	59.5					35.6	105.2	11.09	115.6	.487	65.1
Pork:												
Raw	57	68.1					64.6		3.37		.517	
Fried, 16 min	58	56.6					59.0	93.4	3.25	98.5	.401	79.2
Braised, 12 min	59	59.0					51.7	80.6	3.12	93.3	.524	102.1
Milk:												
Liquid, whole:[9]												
Used in biscuits	60	90.1					.63		2.854		.345	
Used in rolls	61	89.5					.64		3.230		.361	
Used in bread	62	89.8					.74		3.223		.310	
Oats, rolled:												
Raw	63	8.5					.84		.442		.564	
Cooked in double boiler, 30 min., first adding oats to rapidly boiling water.	64	85.0					.98	180.5	.280	59.8	.417	66.8
Cooked in saucepan, 2½ min	65	84.8					.74	166.1			.562	80.6
Peas:												
Dry:												
Raw, Alaska variety	66	7.3			.154		3.2		.485		.675	
Boiled covered, 70 min., water to cover, after soaking 16 hr.	67	73.7			.173	86.2	2.8	67.7	.696	109.8	.502	57.0
Boiled covered, 70 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	68	67.3			.146	92.6	2.5	77.4	.642	129.3	.511	73.9
Raw, Profusion variety	69	6.3			.075		3.2		.920		.690	
Boiled covered, 140 min., water to cover, after soaking 16⅓ hr.	70	67.9			.072	84.7	3.3	86.1	.710	72.0	.349	47.1
Boiled covered, 140 min., water to cover, after soaking 16⅓ hr., then baked uncovered at 350° F., 30 min.	71	65.3			.093	109.3	3.0	79.2	.653	66.4	.576	78.1
Peppers:												
Green:												
Whole, raw	72	93.5	1,943		3.523							
Parboiled 5 min. and baked 40 min	73	92.6	1,728	86.4	3.784	104.4						
Thirds, raw	74	93.8	2,016		3.645							
Baked 60 min.	75	90.5	1,425	69.8	3.758	101.7						
Parboiled 5 min. and baked 40 min	76	92.0	1,565	71.2	3.913	98.5						

See footnotes at end of table.

Table 3.—20 Common Foods: *Vitamin and mineral content[1] per 100 grams dry weight and retention,[2] as affected by various home cooking procedures*—continued

Food and cooking method [3]	Identification No.	Moisture [4]	Ash		Calcium		Phosphorus [5]		Iron	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Corn meal:										
White, raw	43	9.5	1,320		3.32		308		3.0	
Cooked in double boiler, 60 min	44	87.6	1,310	101.3	3.60	99.1	341	113.4	3.0	100.1
Cooked in saucepan, 15 min	45	87.4	1,270	96.7	3.89	118.8	311	101.1	3.1	104.6
Yellow, raw	46	9.4	682		4.96		155		1.6	
Cooked in double boiler, 60 min	47	87.5	686	96.5	5.74	108.1	194	119.2	2.2	133.3
Cooked in saucepan, 15 min	48	87.3	691	99.5	4.10	62.3	156	100.1	2.0	121.4
Flour (used in making biscuits, bread, rolls):										
White, enriched	49	11.8	481		11.2		143		2.5	
Whole-wheat	50	10.4	1,830		31.9		426		5.4	
Liver:										
Beef:										
Raw	51	74.7	5,080				1,330		36.4	
Fried, 13 min	52	55.4	4,090	111.7			1,280	119.0	30.2	102.8
Braised, 15 min	53	52.2	4,420	104.1			1,280	115.6	28.5	94.2
Calf:										
Raw	54	70.1	4,890				1,300		22.3	
Fried, 19 min	55	56.4	4,580	95.7			1,190	93.2	21.4	97.8
Braised, 11½ min	56	59.5	4,700	101.7			1,260	102.5	29.6	140.6
Pork:										
Raw	57	68.1	5,060				1,320		78.9	
Fried, 16 min	58	56.6	5,030	101.7			1,250	96.9	70.3	90.6
Braised, 12 min	59	59.0	5,090	101.7			1,250	95.4	72.6	92.2
Milk:										
Liquid, whole:[9]										
Used in biscuits	60	90.1	7,240		1,190		960		1.0	
Used in rolls	61	89.5	5,680		937		724		.53	
Used in bread	62	89.8	5,780		879		744		.57	
Oats, rolled:										
Raw	63	8.5	2,060		51.7		533		4.2	
Cooked in double boiler, 30 min., first adding oats to rapidly boiling water.	64	85.0	2,040	80.0	48.4	89.7	523	98.9	4.1	110.6
Cooked in saucepan, 2½ min	65	84.8	2,030	83.6	44.7	52.4	534	84.2	4.1	102.0
Peas:										
Dry:										
Raw, Alaska variety	66	7.3	3,060		89.2		464		5.9	
Boiled covered, 70 min., water to cover, after soaking 16 hr.	67	73.7	3,020	75.5	87.1	74.8	485	80.4	5.9	75.6
Boiled covered, 70 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	68	67.3	3,020	96.3	87.2	95.5	473	99.9	6.8	112.3
Raw, Profusion variety	69	6.3	3,340		90.1		494		14.6	
Boiled covered, 140 min., water to cover, after soaking 16⅓ hr.	70	67.9	3,490	97.4	102.0	105.4	511	96.4	7.2	45.8
Boiled covered, 140 min., water to cover, after soaking 16⅓ hr., then baked uncovered at 350° F., 30 min.	71	65.3	3,340	93.6	102.0	106.0	520	98.3	6.4	40.7
Peppers:										
Green:										
Whole, raw	72	93.5	6,050		70.0		338		11.5	
Parboiled 5 min. and baked 40 min	73	92.6	5,520	88.6	66.6	83.6	388	111.3	7.4	62.1
Thirds, raw	74	93.8	6,100		70.0		660		6.5	
Baked 60 min	75	90.5	5,930	95.9	76.3	115.8	354	53.6	5.8	78.4
Parboiled 5 min. and baked 40 min	76	92.0	5,140	77.3	44.9	64.0	360	54.3	7.0	88.5

See footnotes at end of table.

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Table 3.—20 Common Foods: *Vitamin and mineral content*[1] *per 100 grams dry weight and retention,*[2] *as affected by various home cooking procedures*—continued

Food and cooking method [3]	Identification No.	Moisture [1]	Ascorbic acid		Carotene		Nicotinic acid		Riboflavin		Thiamine	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Pork:												
Loin chops:												
Raw	77	[4]70.1					14.4		0.254		2.12	
Fried, 15 min	78	[4]46.4					7.91	67.0	.215	103.4	1.13	65.2
Braised, 30 min	79	[4]47.3					9.47	79.7	.191	91.4	1.28	73.5
Rolls:												
White, enriched:												
Raw ingredients [5]	80											
Baked at 425° F., 14 min	81	24.7					1.81	101.0	.757	142.3	.273	69.4
Baked at 425° F., 14 min	82	26.1					1.79	108.1	.729	148.4	.256	70.3
Whole-wheat:												
Raw ingredients [5]	83											
Baked at 425° F., 14 min	84	28.1					4.42	100.8	.795			
Baked at 425° F., 14 min	85	25.4					4.49	104.3	1.039	115.9	.238	64.5
Rutabaga:												
Raw	86	88.6	279.4		Pigment not carotene				.671		.312	
Boiled cubed uncovered, 22½ min., 1.15 ml. water per gm. food.	87	89.9	182.2	52.6					.653	78.6	.228	59.1
Boiled cubed uncovered, 22½ min., 1.15 ml. water per gm. food, then mashed.	88	89.3	158.6	49.1					.547	70.5		
Sweetpotatoes:												
Whole, unpared:												
Raw	89	62.7	81.4		11.667							
Boiled uncovered, 46 min., 1.05 ml. water per gm. food.	90	65.1	96.4	114.8	10.707	89.2						
Baked at 425° F., 65 min	91	55.9	76.7	89.5	10.775	87.9						
Halves, unpared:												
Raw	92	65.3	86.8		14.562				.152			
Baked at 425° F., 48 min	93	55.7	27.1	31.1	12.982	88.7			.150	97.8		
Turnips (Purple Top variety):												
Pared, sliced:												
Raw	94	91.1	295						1.889			
Boiled uncovered, 19½ min., 0.89 ml. water per gm. food.	95	91.8	211.3	61.5					1.677	76.7		
Pared, whole:												
Raw	96	92.2	310.9						2.147			
Boiled uncovered, 40 min., 1.69 ml. water per gm. food.	97	92.4	193.2	48.7					1.783	65.1		
Pared (sampled thirds), sliced:												
Raw	98	91.6	288.9						.889			
Boiled uncovered, 16 min., 0.89 ml. water per gm. food.	99	92.6	208.9	60.4					1.669	69.7		
Boiled uncovered, 16 min., 0.89 ml. water per gm. food, then mashed.	100	92.6	176.9	49.2					1.256	80.4		
Turnip greens:												
Raw	101	91.9	842		43.296		7.3		7.765			
Boiled covered, 13 min., 1.47 ml. water per gm. food.	102	92.6	386	39.5	63.284	136.0	9.5	116.6	6.000	66.5		
Boiled covered, 60 min., 1.47 ml. water per gm. food.	103	91.6	232	27.1	54.300	124.5	10.1	137.3	6.761	86.5		
Yeast:												
Compressed (used in making rolls and bread)	104	71.3					42.5		8.150		1.89	

[1] Based on drained weight of food except dry lima beans, items numbered 8 and 9; dry navy beans, items 11 and 12; and dry peas, items 67, 68, 70, and 71, where the cooking liquid was included with the food for analysis. Also, the drippings were analyzed with the meat for beef, calf, and pork livers, items numbered 52, 53, 55, 56, 58, and 59; beef pot roasts, items 20 and 22; and braised pork chops, item 79.

[2] Retention is calculated on the basis of the drained food except for the items listed in footnote No. 1. Retention is based on the formula: $\frac{\text{content per gm. cooked} \times \text{cooked wt. (gm.)}}{\text{content per gm. raw} \times \text{raw wt. (gm.)}} \times 100$.

[3] See table 1 for details as to size of raw sample and volume of water.

Table 3.—20 Common Foods: *Vitamin and mineral content*[1] *per 100 grams dry weight and retention,*[2] *as affected by various home cooking procedures*—continued

Food and cooking method [3]	Identification No.	Moisture [4]	Ash		Calcium		Phosphorus		Iron	
			Content	Retention	Content	Retention	Content	Retention	Content	Retention
		Pct.	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Pork:										
Loin chops:										
Raw	77	[4]70.1	2,023				415		3.95	
Fried, 15 min	78	[4]46.4	1,343	81.3			306	90.2	1.86	57.5
Braised, 30 min	79	[4]47.3	1,269	76.3			248	72.6	1.94	59.6
Rolls:										
White, enriched:										
Raw ingredients [5]	80									
Baked at 425° F., 14 min	81	24.7	1,760		75.6		178		3.9	
Baked at 425° F., 14 min	82	26.1	1,790		73.7		173		2.5	
Whole-wheat:										
Raw ingredients [5]	83									
Baked at 425° F., 14 min	84	28.1	2,820		89.5		428		4.0	
Baked at 425° F., 14 min	85	25.4	2,830		84.8		441		3.8	
Rutabaga:										
Raw	86	88.6	4,470		258		249		3.3	
Boiled cubed uncovered, 22½ min., 1.15 ml. water per gm. food.	87	89.9	3,950	71.3	283	91.1	299	97.6	3.2	57.5
Boiled cubed uncovered, 22½ min., 1.15 ml. water per gm. food, then mashed.	88	89.3	4,200	81.2	228	77.6	278	98.8	2.5	65.2
Sweetpotatoes:										
Whole, unpared:										
Raw	89	62.7	1,920		64.8		121		2.0	
Boiled uncovered, 46 min., 1.05 ml. water per gm. food.	90	65.1	2,080	105.3	57.7	86.6	107	85.4	2.2	109.5
Baked at 425° F., 65 min	91	55.9	2,500	123.7	74.7	110.6	105	82.3	1.6	79.7
Halves, unpared:										
Raw	92	65.3	2,150		71.8		126		1.6	
Baked at 425° F., 48 min	93	55.7	2,140	99.0	50.7	71.2	96	75.7	2.6	157.8
Turnips (Purple Top variety):										
Pared, sliced:										
Raw	94	91.1	6,430		547		463		3.1	
Boiled uncovered, 19½ min., 0.89 ml. water per gm. food.	95	91.8	6,070	81.3	567	87.7	500	93.4	3.5	99.6
Pared, whole:										
Raw	96	92.2	6,620		564		491		3.3	
Boiled uncovered, 40 min., 1.69 ml. water per gm. food.	97	92.4	5,700	67.5	496	69.5	427	67.8	3.6	84.5
Pared (sampled thirds), sliced:										
Raw	98	91.6	6,210		534		475		2.7	
Boiled uncovered, 16 min., 0.89 ml. water per gm. food.	99	92.6	5,580	75.0	508	80.1	402	71.0	3.0	92.8
Boiled uncovered, 16 min., 0.89 ml. water per gm. food, then mashed.	100	92.6	5,510	71.3	502	75.0	412	68.4	3.3	97.7
Turnip greens:										
Raw	101	91.9	19,940		3,500		749		33.4	
Boiled covered, 13 min., 1.47 ml. water per gm. food.	102	92.6	13,540	58.2	2,650	65.0	658	75.7	32.7	84.1
Boiled covered, 60 min., 1.47 ml. water per gm. food.	103	91.6								
Yeast:										
Compressed (used in making rolls and bread)	104	71.3	6,150		14.4		1,150		17.4	

[4] Moisture is for meat only, exclusive of fat and bone; for chicken, skin was also omitted.
[5] Calculated on the basis of the value for items numbered 49 or 50; 60, 61, or 62; and 104 (except for biscuits).
[6] Carotene values calculated from vitamin A values of 805 I. U. for items numbered 40; 835 I. U. for 41; and 886 I. U. for 42, on basis of I. U.=0.6 mcg. of carotene.
[7] Assay by rat-growth method.
[8] Carotene values calculated from vitamin A values of 280 I. U. for items numbered 46; 315 I. U. for 47; and 380 I. U. for 48, on basis of I. U.=0.6 mcg. of carotene.
[9] Mg. per 100 ml.

Table 4.—20 Common Foods: *Vitamin and mineral content [1] per 100 grams wet weight, as affected by various home cooking procedures*

Food and cooking method [2]	Identification No.	Moisture [1]	Ascorbic acid	Carotene	Nicotinic acid	Riboflavin	Thiamine	Ash	Calcium	Phosphorus	Iron
		Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Beans:											
Lima:											
Fresh, raw, Henderson variety	1	67.6	21.7	0.141			0.245	1,900	51.2	179.0	2.650
Boiled covered, 30 min., 0.47 ml. water per gm. food	2	65.2	8.5	.137			.138	1,560	45.2	159.0	2.560
Boiled covered, 30 min., 0.94 ml. water per gm. food	3	66.6	5.3	.148			.089	1,210	31.8	142.0	2.120
Frozen, raw	4	60.2	3.1	.035	0.641	0.424	.165	1,460	29.5	184.0	2.900
Boiled unthawed, covered, 16 min., 0.47 ml. water per gm. food.	5	66.7	1.1	.027	.535	.238	.115	1,200	23.3	138.0	2.510
Boiled unthawed, covered, 16 min., 0.94 ml. water per gm. food.	6	69.1	1.1	.023	.385	.314	.111	921	22.2	127.0	2.200
Dry, raw	7	10.1			1.780		.608	4,410	56.6	347.0	8.620
Boiled covered, 82 min., water to cover, after soaking 16 hr.	8	76.6			.471		.106	1,350	16.5	99.3	2.330
Boiled covered, 77 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	9	71.5			.500		.106	1,390	17.9	108.0	2.590
Dry, raw	7	8.2			1.610	.650	.622	4,470	59.6	316.0	8.600
Boiled covered, 82 min., water to cover, after soaking 16 hr.	8	71.3			.447	.202	.124	1,370	19.8	107.0	2.800
Boiled covered, 77 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	9	67.9			.467	.210	.145	1,550	20.2	119.0	2.800
Navy:											
Dry, raw	10	7.1			2.080	.395	.584	3,520	170.0	423.0	7.630
Boiled covered, 30 min., water to cover, after soaking 16 hr., then baked covered 250° F., 360 min.	11	70.4			.567	.163	.105	1,170	47.3	140.0	2.550
Boiled covered, 120 min., water to cover, after soaking 16 hr., then baked uncovered 350° F., 30 min.	12	67.9			.620	.167	.162	1,240	54.6	148.0	3.020
Dry, raw	10	6.9			1.940	.581	.641	3,460	156.0	407.0	8.510
Boiled covered, 30 min., water to cover, after soaking 16 hr., then baked covered 250° F., 360 min.	11	71.3			.492	.262	.096	1,060	51.7	128.0	2.730
Boiled covered, 120 min., water to cover, after soaking 16 hr., then baked uncovered 350° F., 30 min.	12	65.6			.591	.296	.186	1,300	60.2	152.0	2.890
Snap:											
Raw, Bountiful variety	13	86.9	20.2					778	46.2	47.2	1.280
Boiled covered, 1-in. pieces, 25 min., 0.88 ml. water per gm. food.	14	88.4	8.8	.334				643	45.5	50.5	.890
Boiled covered, 1-in. pieces, 120 min., 0.88 ml. water per gm. food.	15	88.5	7.2	.270				589	49.0	44.3	.870
Wax:											
Raw, Pencil Pod variety	16	88.0	21.1					880	48.5	56.4	.874
Boiled covered, 1-in. pieces, 31 min., 0.77 ml. water per gm. food.	17	90.0	11.5					759	47.7	50.0	.820
Boiled covered, 1-in. pieces, 120 min., 0.77 ml. water per gm. food.	18	88.1	8.1					900	57.2	61.2	1.010

Beef:											
Pot roast, chuck:											
Left side, raw	19	[3]71.6			2.220	.169		601		104.8	1.670
Braised 222 min., no water	20	[3]46.0			2.830	.277		824		153.8	1.260
Right side, raw	21	[3]71.1			2.350	.190		649		115.0	1.720
Braised 244 min., water added	22	[3]64.5			2.680	.211		747		141.0	2.200
Biscuits:											
White, enriched:											
Raw ingredients [4]	23				.734	.236	.202				
Baked at 425° F., 14 min.	24	20.2			.920	.482	.223	3,410	140.0	246.0	5.080
Whole-wheat:											
Raw ingredients [4]	25				2.290	.338	.206				
Baked at 425° F., 14 min.	26	16.9			2.340	.586	.247	4,370	158.0	420.0	6.680
Bread:											
White, enriched:											
Raw ingredients [4]	27				1.010	.305	.233				
Baked at 375° F., 40 min.	28	31.6			1.420	.686	.183	1,780	56.0	131.0	1.590
Whole-wheat:											
Raw ingredients [4]	29				2.720	.418	.240				
Baked at 375° F., 40 min.	30	32.7			3.180	.690	.259	2,350	70.0	312.0	3.130
Cabbage:											
Green, raw	31	91.9	57.4	.025		.295		749	53.3	33.6	.451
Boiled uncovered, 1-in. strips, 10 min., 2.08 ml. water per gm. food.	32	93.4	24.7	.008		.200		457	41.1	26.7	.372
Boiled uncovered, 1-in. strips, 60 min., 2.08 ml. water per gm. food.	33	93.9	14.5	.009		.135		423	38.9	26.9	.308
Green, raw	31	92.4	60.4	.033	.238	.131		652	43.0	36.3	.366
Boiled uncovered, 1-in. strips, 10 min., 2.08 ml. water per gm. food.	32	94.8	23.6	.024	.116	.066		333	25.5	26.0	.328
Boiled uncovered, 1-in. strips, 60 min., 2.08 ml. water per gm. food.	33	94.8	11.8	.024	.112	.071		399	30.0	30.8	.255
White, raw	34	91.3	40.9	.008				721	63.7	34.9	.305
Boiled uncovered, 1-in. strips, 10 min., 2.08 ml. water per gm. food.	35	94.0	17.1	.005				384	42.8	21.5	.302
Boiled uncovered, 1-in. strips, 60 min., 2.08 ml. water per gm. food.	36	93.5	13.4	.005				445	47.1	26.3	.284
Chicken (Rhode Island Red):											
Raw (dark and light meat)	37	[3]70.7			5.52	.058		542		106.2	1.04
Simmered disjointed, covered, 240 min., water to cover	38	[3]59.7			2.84	.068		417		94.0	1.16
Boiled disjointed, covered, 194 min., water to cover	39	[3]58.6			2.77	.049		408		89.5	1.11
Raw (dark meat)	37a				11.1	.139		1,110		211	2.6
Simmered disjointed, covered, 240 min., water to cover	38a				4.2	.119		800		175	2.4
Boiled disjointed, covered, 194 min., water to cover	39a				4.7	.096		870		190	2.8
Raw (light meat)	37b				11.9	.094		1,150		232	1.5
Simmered disjointed, covered, 240 min., water to cover	38b				7.0	.141		750		179	1.8
Boiled disjointed, covered, 194 min., water to cover	39b				7.0	.106		792		174	1.5

See footnotes at end of table

Table 4.—20 Common Foods: ***Vitamin and mineral content*** [1] ***per 100 grams wet weight, as affected by various home cooking procedures*—continued**

Food and cooking method [2]	Identification No.	Moisture [1]	Ascorbic acid	Carotene	Nicotinic acid	Riboflavin	Thiamine	Ash	Calcium	Phosphorus	Iron
		Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Corn:											
Fresh, raw, Golden Bantam variety	40	75.9	12.4	[5]0.116	----	----	[6]0.141	716	1.3	110.0	0.619
Boiled covered, 10 min., 0.45 ml. water per gm. food	41	75.7	8.7	[5].122	----	----	[6].109	569	1.6	88.5	.507
Boiled covered, 30 min., 0.90 ml. water per gm. food	42	79.8	5.3	[5].107	----	----	[6].075	473	1.4	79.1	.448
Corn meal:											
White, raw	43	9.5	----	----	----	0.560	.213	1,180	3.0	275.0	2.700
Cooked in double boiler, 60 min	44	87.6	----	----	----	.068	.030	161	.4	42.0	.364
Cooked in saucepan, 15 min	45	87.4	----	----	----	.076	.034	160	.5	39.0	.396
Yellow, raw	46	9.4	----	[7].155	1.650	.405	.152	618	4.5	140.0	1.460
Cooked in double boiler, 60 min	47	87.5	----	[7].024	.242	.042	.018	86	.7	24.0	.280
Cooked in saucepan, 15 min	48	87.3	----	[7].020	.218	----	.021	88	.4	20.0	.253
Flour (used in making biscuits, bread, and rolls):											
White, enriched	49	11.8	----	----	1.480	.262	.389	424	9.9	126.0	2.180
Whole-wheat	50	10.4	----	----	4.720	.475	.397	1,640	28.6	382.0	4.850
Liver:											
Beef:											
Raw	51	74.7	----	----	17.800	4.010	.151	1,290	----	337.0	9.210
Fried 13 min	52	55.4	----	----	25.800	5.330	.208	2,050	----	571.0	13.470
Braised 15 min	53	52.2	----	----	----	5.330	.116	2,110	----	612.0	13.630
Calf:											
Raw	54	70.1	----	----	10.700	3.040	.234	1,460	----	389.0	6.670
Fried 19 min	55	56.4	----	----	16.000	4.430	.243	2,000	----	519.0	9.340
Braised 11½ min	56	59.5	----	----	14.400	4.490	.195	1,900	----	510.0	12.000
Pork:											
Raw	57	68.1	----	----	20.600	1.080	.165	1,610	----	421.0	25.300
Fried 16 min	58	56.6	----	----	25.600	1.410	.174	2,180	----	543.0	30.500
Braised 12 min	59	59.0	----	----	21.200	1.280	.215	2,090	----	513.0	29.800
Milk:											
Liquid, whole: [8]											
Used in biscuits	60	90.1	----	----	.062	.283	.041	717	118.0	95.0	.101
Used in rolls	61	89.5	----	----	.067	.339	.045	716	118.0	91.2	.067
Used in bread	62	89.8	----	----	.076	.329	.038	717	109.0	92.3	.070
Oats, rolled:											
Raw	63	8.5	----	----	.773	.405	.152	618	4.5	140.0	1.460
Cooked in double boiler, 30 min., first adding oats to rapidly boiling water.	64	85.0	----	----	.242	.042	.018	86	.7	24.0	.280
Cooked in saucepan, 2½ min	65	84.8	----	----	.218	----	.021	88	.4	20.0	.253

Peas:											
Dry:											
Raw, Alaska variety	66	7.3		.143	2.980	.450	.626	2,840	82.7	430.0	.550
Boiled covered, 70 min., water to cover, after soaking 16 hr.	67	73.7		.046	.747	.183	.132	794	22.9	128.0	1.540
Boiled covered, 70 min., water to cover, after soaking 16 hr., then baked uncovered at 350° F., 30 min.	68	67.3		.048	.833	.210	.167	988	28.5	155.0	2.230
Raw, Profusion variety	69	6.3		.075	3.320	.862	.647	3,130	84.4	463.0	13.730
Boiled covered, 140 min., water to cover, after soaking 16⅓ hr.	70	67.9		.023	1.050	.228	.112	1,120	32.7	164.0	2.300
Boiled covered, 140 min., water to cover, after soaking 16⅓ hr., then baked uncovered at 350° F., 30 min.	71	65.3		.032	1.040	.227	.200	1,160	35.4	180.0	2.210
Peppers:											
Green:											
Whole, raw	72	93.5	126.3	.229				393	5.0	22.0	.749
Parboiled 5 min. and baked 40 min.	73	92.6	127.9	.280				408	4.9	28.7	.545
Thirds, raw	74	93.8	125.0	.226				378	4.0	34.0	.450
Baked 60 min.	75	90.5	135.4	.357				563	7.2	33.6	.548
Parboiled 5 min. and baked 40 min.	76	92.0	125.2	.313				411	3.6	26.0	.560
Pork:											
Loin chops:											
Raw	77	[3]70.1			7.920	.140	1.160	1,110		228.0	2.170
Fried 15 min.	78	[3]46.4			7.350	.200	1.050	1,250		285.0	1.730
Braised 30 min.	79	[3]47.3			9.690	.196	1.310	1,300		254.0	1.990
Rolls:											
White, enriched:											
Raw ingredients [4]	80				.990	.294	.218				
Baked at 425° F., 14 min.	81	24.7			1.360	.570	.206	1,330	57.0	134.0	2.960
Baked at 425° F., 14 min.	82	26.1			1.320	.539	.189	1,320	54.0	128.0	1.840
Whole-wheat:											
Raw ingredients [4]	83				2.600	.400	.224				
Baked at 425° F., 14 min.	84	28.1			3.180			2,030	64.0	308.0	2.880
Baked at 425° F., 14 min.	85	25.4			3.350	.572	.178	2,110	63.0	329.0	2.810
Rutabagas:											
Raw	86	88.6	31.9			.076	.036	510	29.0	28.0	.382
Boiled cubed uncovered, 22½ min., 1.15 ml. water per gm. food.	87	89.9	18.4			.066	.024	399	29.0	30.0	.241
Boiled cubed uncovered, 22½ min., 1.15 ml. water per gm. food, then mashed.	88	89.3	17.0			.058	.038	449	24.4	30.0	.270
Sweetpotatoes:											
Whole, unpared:											
Raw	89	62.7	30.4	4.352				716	24.0	45.0	.735
Boiled uncovered, 46 min., 1.05 ml. water per gm. food	90	65.1	33.6	3.737				726	20.0	37.0	.775
Baked at 425° F., 65 min.	91	55.9	33.8	4.752				1,100	33.0	46.0	.728
Halves, unpared:											
Raw	92	65.3	30.1	5.053		.053		746	25.0	44.0	.569
Baked at 425° F., 48 min.	93	55.7	12.1	5.790		.067		954	23.0	43.0	1.160

See footnotes at end of table.

Table 4.—20 Common Foods: ***Vitamin and mineral content*** [1] ***per 100 grams wet weight, as affected by various home cooking procedures*—continued**

Food and cooking method [2]	Identification No.	Moisture [1]	Ascorbic acid	Carotene	Nicotinic acid	Riboflavin	Thiamine	Ash	Calcium	Phosphorus	Iron
		Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Turnips (Purple Top variety):											
Pared, sliced:											
Raw	94	91.1	26.3	----	----	0.168	----	572	49.0	41.0	0.272
Boiled uncovered, 19½ min., 0.89 ml. water per gm. food.	95	91.8	17.3	----	----	.138	----	498	46.0	41.0	.290
Pared, whole:											
Raw	96	92.2	24.2	----	----	.168	----	516	44.0	38.0	.260
Boiled uncovered, 40 min., 1.69 ml. water per gm. food, then sliced.	97	92.4	14.7	----	----	.136	----	433	38.0	32.0	.273
Pared (sampled thirds), sliced:											
Raw	98	91.6	24.3	----	----	.168	----	522	45.0	40.0	.225
Boiled uncovered, 16 min., 0.89 ml. water per gm. food	99	92.6	15.5	----	----	.124	----	413	38.0	30.0	.220
Boiled uncovered, 16 min., 0.89 ml. water per gm. food, then mashed.	100	92.6	13.1	----	----	.148	----	408	37.0	30.0	.241
Turnip greens:											
Raw	101	91.9	68.2	3.507	0.569	.629	----	1,620	284.0	61.0	2.710
Boiled covered, 13 min., 1.47 ml. water per gm. food	102	92.6	28.6	4.683	.704	.444	----	1,000	196.0	49.0	2.420
Boiled covered, 60 min., 1.47 ml. water per gm. food	103	91.6	19.5	4.562	.816	.568	----	----	----	----	----
Yeast:											
Compressed (used in making rolls and bread)	104	71.3	----	----	12.200	2.340	0.543	1,770	3.5	330.0	4.980

[1] Based on drained weight of food except dry lima beans, items numbered 8 and 9; dry navy beans, items 11 and 12; and dry peas, items 67, 68, 70, and 71 where the cooking liquid was included with the food for analysis. Also the drippings were analyzed with the meat for beef, calf, and pork livers; items numbered 52, 53, 55; 56, 58, and 59; beef pot roast, items 20 and 22, and braised pork chops, item 79.

[2] See table 1 for details as to size of raw sample and volume of water.

[3] Moisture is for meat only, exclusive of fat and bone; for chicken, skin was also omitted.

[4] Calculated on the basis of the value for items numbered 49 or 50; 60, 61, or 62; and 104 (except for biscuits).

[5] Carotene values calculated from vitamin A values of 194 I. U. for items numbered 40; 203 I. U. for 41; and 179 I. U. for 42 on basis of I. U.=0.6 mcg. of carotene.

[6] Assay by rat-growth method.

[7] Carotene values calculated from vitamin A values of 254 I. U. for items numbered 46; 39.4 I. U. for 47; and 33.2 I. U. for 48 on basis of I. U.=0. 6 mcg. of carotene.

[8] Mg. per 100 ml.

POTATOES

Potatoes cooked in any one of a large variety of ways probably appear on menus in this country more often than any other vegetable. In the popular mind they are associated most often with calories. But in nutritive value potatoes are also important for other reasons. An analysis of the per capita national food supply from 1909 to 1945 (*17*) shows that potatoes as brought into the kitchen furnished one-fifth or more of the ascorbic acid and about one-tenth of the niacin and thiamine. Because of their dietary importance, potatoes were chosen for detailed study in this series of experiments.

Different methods of home cooking were compared in their effect on retention of selected nutrients. Analyses of ascorbic and dehydroascorbic acid, nicotinic acid, thiamine, moisture, and ash were made on selected varieties of potatoes cooked by different methods. Fat was determined in fried potatoes.

Variety and Storage

Three varieties of potatoes were used—Katahdin, Green Mountain, Chippewa. After detailed experiments with Katahdin had been completed, the other two varieties were included to give a more representative sample of potatoes available in the Washington, D. C., market and to investigate additional methods of cooking.

Katahdin.—Potatoes of the Katahdin variety, U. S. No. 1, Maine-grown, were purchased in one lot on the local market. Upon delivery to the laboratory, the potatoes were sorted as to size and weight. Those selected for study were 2¼ to 2½ inches in diameter and weighed 100 to 200 gm. They were put in burlap sacks and placed in storage at 40° F., and 85-percent relative humidity. The experiments with these potatoes were carried out during two periods, namely, Nov. 10, 1943, through Jan. 19, 1944, and April 24 through May 24, 1944; hence the potatoes used in the last group of experiments had been in storage 5½ to 6½ months.

For representative sampling, the same number of potatoes was taken for analysis from each sack. During the first period, the potatoes were removed from storage, washed, separated into portions each containing approximately 680 gm. (4 to 6 potatoes), and held 18 to 42 hours in the laboratory at 60° to 75° F., prior to being cooked and analyzed.

During the second period, the potatoes were conditioned by removal from cold storage to an air-conditioned room at 70° F., 1 week before use. This conditioning period was used because cold storage tends to increase the sugar content; whereas higher environmental temperatures tend to reverse the reaction (*4*, *74*). As in the first period, the potatoes were held in the laboratory before use. Sprouts that had formed were removed when the potatoes were washed in preparation for cooking and analysis.

Green Mountain.—Potatoes of the Green Mountain variety were purchased on the Washington, D. C., market, one lot at the beginning and another toward the end of November, 1945. The first series of experiments was conducted immediately, November 13 to 19, and the second during the week of December 3 to 10. In order to simulate more nearly home cooking conditions, the Green Mountain potatoes were not sized with the same exactness used for the Katahdins; however, extremes, i.e., very large or very small tubers, were excluded.

The first lot of potatoes was held at 70° F. and withdrawn at random as needed. The second lot of potatoes was separated into medium mealy and nonmealy by a salt-density test (*63*). Since the lot was predominantly nonmealy, only the nonmealy were used. They were divided into 680-gm. portions, placed in paper bags, and held at 70° F.

Chippewa.—Chippewa potatoes were purchased on the Washington, D. C., market in the middle of January 1946. These potatoes were somewhat soft and watery, which suggested possible exposure to freezing temperatures. According to a salt-density test (*63*), the potatoes were predominantly nonmealy. Therefore, only the nonmealy ones were chosen for study.

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The required number of portions to be analyzed raw and cooked were weighed out and held at 70° F. as described for the second lot of Green Mountains.

The cooking experiments, with the exception of French frying, were completed within 16 days of the purchase of the potatoes. The French fries prepared for palatability evaluations during this period were of poor quality. Upon testing (*59*), the raw potatoes were found to contain excessive accumulation of soluble sugars, which causes caramelization in French fried potatoes. Therefore, to lower the sugar content and improve the quality, the potatoes were further conditioned by storage at 70° F. for 17, 24, and 36 days (*4*, *24*, *74*), with improvement in flavor and color of the French fries.

Preparation, Cooking, Sampling

Details of preparation, method of cooking, weight of raw and cooked food, volume of water and residual liquid, and cooking time for potatoes are presented in table 5. Stainless steel knives were used. The volume of water for each method was selected after preliminary cooking tests with the Katahdin potatoes to make sure that the lowest volume was at a practical level above the minimum to prevent scorching before the end of the cooking period.

The cooking times were based on palatability evaluations of the cooked product, and in some cases on the puncture test for tenderness. The puncture test was used as a check during the cooking of Green Mountains and Chippewas for analysis. In preliminary tests on Katahdins baked and boiled whole, thermometers were inserted to establish the cooking time. Thermometers were not used in the potatoes cooked for analysis because the formation of holes would invalidate the solubility and baking results.

Heat-penetration measurements could not be made since potentiometers and thermocouples were unobtainable owing to war shortages.

All potatoes cooked in water or steam were drained as described on page 3. Those cooked in fat were drained quickly on absorbent paper. Weights of the raw and cooked potatoes were determined at room temperature which averaged 77° F. All cooked potatoes were cooled to 77° F. by immersing the utensils containing the hot vegetable in cracked ice. Residual cooking liquid was cooled similarly.

Control of Cooking Conditions

For top-of-stove cooking, three two-burner table-model stoves were used, each equipped with a pressure regulator and a meter. Manufactured gas was employed. The rate of the flow of gas was regulated by hand, every care being exercised to keep it uniform for a given cooking method.

In the study of Katahdin potatoes, the two burners of each stove were used simultaneously; hence gas-consumption records represented the total for two cooking portions. Although these stoves were designed to provide equal flow of gas in each burner, some difference between burners was observed. For close laboratory control, therefore, great care in manual adjustment of burners was necessary to maintain comparable flames for both burners on each stove.

Closer control of the rate of gas flow in later experiments with Green Mountain and Chippewa potatoes was obtained since only one of the burners on each stove was used at any one time. The fuel consumption for each cooking portion was thus obtained, rather than the average derived from the total for the two cooked at the same time on one stove.

Boiling.—Studies were made using pared and unpared whole potatoes, and pared quartered potatoes. The experiments included soaking before cooking, salting the cooking water, and using different quantities of water. Boiling was done in 3-quart covered enameled pans. Water was boiled 3 minutes before the potatoes were added.

In the study of the effect of salting, sodium chloride was added to the water prior to boiling. In the study of the effect of soaking, whole pared potatoes were held overnight in distilled water at room temperature before being cooked.

Cooking in a pressure saucepan.—Pared quartered potatoes were cooked in a 3-quart aluminum pressure saucepan at 15 pounds for 8 minutes. Besides the 8 minutes, there was a heating

time of 2½ to 4½ minutes which included 1 minute for escape of air and steam. As soon as the cooking was completed, the saucepan was placed in cold water, which caused the pressure to drop to zero within 30 seconds.

Mashing.—For mashing, potatoes that had been boiled whole, pared or unpared, were used. They were peeled when necessary, quartered longitudinally, put through a ricer, and the process completed by beating with a fork or a wire masher. Pared quartered potatoes that had been boiled and pressure-cooked were also mashed in the same manner. No milk or seasonings were added.

Hash-browning.—Whole unpared and pared potatoes were boiled as described under Boiling (p. 30). After being held overnight in a refrigerator at 40° F., they were cut into cubes and slowly browned in fat in an uncovered aluminum skillet. The fat used was hydrogenated cottonseed oil for the Katahdins and peanut oil (*41*) for the Chippewas and Green Mountains. The potatoes were turned occasionally for even browning.

Country frying.—Raw pared potatoes were cut in slices ⅛ inch thick and browned in a covered aluminum skillet. The fat used was peanut oil and the potatoes were turned occasionally.

French frying.—Pared potatoes were cut lengthwise in strips with ⅜- by ⅜-inch cross section, soaked for 15 minutes in an equal weight of water at room temperature, drained, dried with cheesecloth, and fried in two steps[3] as follows: A sheet-iron frying kettle fitted with a wire basket was used. Three times as much peanut oil by weight as potatoes was heated to 195° C. (383° F.). Portions of the potatoes were "par-fried" for 2 minutes, removed, and drained on absorbent paper. Frying was completed by cooking all the "par-fries" together in the fat preheated to 210° C. (410° F.). In about 9 minutes, when the temperature of the oil returned to 180° C. (356° F.), the potatoes were removed and drained on absorbent paper.

[3] ALEXANDER, L. M., SCHOPMEYER, G. E., and BERGREN, R. E. METHODS OF FRENCH FRYING POTATOES. Paper presented at meeting of Amer. Home Econ. Assoc., Cleveland, 1946. [Unpublished.]

Baking.—Baking was done in an electric oven preheated to 425° F. and maintained at this temperature throughout the baking period. Doneness was determined as described on page 30.

Sampling Methods

For Katahdin potatoes, two methods of cooking were compared on one day. For both methods, three identical portions each sufficient for six servings and weighing approximately 680 gm. (4 to 6 potatoes) were cooked simultaneously, then composited before sampling for analysis. Three similar portions were composited for the raw sample.

For Chippewa and Green Mountain potatoes, three methods of cooking were usually compared on a given day, but only one 680-gm. portion was cooked by each method, except for frying. The portions were randomized with respect to day and cooking method.

Both raw and cooked samples of all varieties were analyzed without the skin. The method of sampling for analysis of nutrients varied slightly, depending on whether or not the potatoes had been cooked whole or in quarters or slices.

For sampling whole potatoes, raw, boiled or baked, pared or unpared, each tuber was quartered longitudinally (from bud to stem end) and distributed into four samples. A quarter from each potato was included in the sample for determining each nutrient. Subsampling of the quarters, when necessary, was carried out by further longitudinal cutting. To eliminate oxidation effects as much as possible, ascorbic acid assays were made on a longitudinal center slice from every quarter. The resulting slices were dropped immediately into a series of tared blendors containing the appropriate extractant.

For sampling quartered potatoes, opposite quarters of raw pared potatoes were dealt into two portions—one for the raw sample, the other for cooking.

The quarters in the raw sample were sliced longitudinally into three pieces (twelfths of a potato) and distributed into three portions for analysis of the nutrients, with outer and inner slices evenly allocated to the portions. Also care was taken in subsampling to insure that each

blendor contained either an outer or an inner slice from every twelfth, in the ratio of two outer to one inner slice.

The quarters from the cooked sample were cut and distributed as for raw, except in the subsampling. The blendor contained two outer and one inner slice from every twelfth. This equalized the oxidative effects among the samples and the solubility effects of the cooking water.

The residual cooking liquid in the case of the three identical cooked portions of Katahdins was composited before analysis.

Mashed, hash-browned, or country fried potatoes were spread on trays and spoonfuls taken from various parts of the trays for analysis. The potatoes for French frying were cut lengthwise into strips with ⅜- by ⅜-inch cross section. For the raw and cooked samples, short and long strips were taken in equal numbers. After frying, equal numbers of short and long strips were distributed for analysis of each nutrient.

Methods of Analysis

For effective extraction of the vitamins, known weights of potato sample and acid were placed in blendors and homogenized. A weighed amount of the resulting mix was used for analysis. In the case of fried potatoes, ether was used to remove the fat from the acid extract before proceeding with the analysis.

In assaying vitamins chemically or microbiologically, experience has demonstrated the advisability of testing for completeness of extraction of the vitamin from the food, and for the presence of interfering substances. In this investigation the size of the samples was varied in ratios of 1, 3, and 5. The analytical results thus obtained were plotted against the weight of the sample. When a straight line was obtained, adequacy of extraction was certain; it was also probable that interfering substances were absent. A curved line indicated incomplete extraction or interfering substances.

In the case of a curved line, the vitamin-containing solutions were diluted in the ratio of 1:1, 1:2, and 3:5. Failure of the lines to coincide when the values for the dilution for any given size sample fell on a straight line indicated incomplete extraction.

If the line for a large sample was below that of a smaller sample, increasing the volume of extractant often corrected the condition. On the other hand, if values obtained by dilution of a sample failed to decrease proportionally, interfering substances were probably present. The figures thus obtained, when plotted against sample size, tended to fall on a parabolic or hyperbolic curve.

If the concentration of the vitamin was greater than that of the interfering substances, it was possible to dilute the sample until the interfering substances no longer exerted any effect, as in the case of thiamine (*48*, *58*) or riboflavin. (See Appendix C, p. 73.) Otherwise, it was necessary to analyze for interfering substances, as glucoreductones in case of ascorbic acid; or to concentrate the extracts and remove the interfering substances by the use of specific adsorbents, as in the case of the B-vitamins. Adsorption with zeolite (*18*) was found efficient in separating substances from the thiamine extracts, and florisil (*26*) was employed for riboflavin.

Ascorbic acid was determined by the indophenol titration method as described on page 7. Dehydroascorbic acid was reduced with hydrogen sulfide and the total ascorbic acid determined in the same manner. The method of Gunther (*31*) for dehydroascorbic acid was tried without success. The potentiometric procedure of Harris, Mapson, and Wang (*32*) was employed to check the visual titrations. For this vitamin, samples approximately 50 gm. in size were placed in a blendor containing 200 gm. of the acid solution. With larger samples extraction was incomplete. At least two 50-gm. aliquots of the blend, corresponding to 9 to 15 gm. of the original potatoes, were withdrawn from each blendor for analysis.

Tests were made for protein-bound ascorbic acid (*21*, *60*). For the determination of reductones, a modification of the method described by Mapson was used (*52*), since it proved more applicable than that of Wokes and others (*72*, *73*). It was found that 25 percent metaphosphoric acid stopped the condensation of ascorbic

acid with formaldehyde as well as did the 50 percent sulfuric acid which Mapson recommended. The rate of reaction varied widely; condensation was so rapid in some instances that titratability was zero after 10 minutes. In spite of the differences in speed of reaction, pH 1.8 to 2.0 was still optimum. To obtain a curve for extrapolation, it was necessary to titrate at 15, 30, 45, and 60 seconds and at minute intervals thereafter. Consequently, instead of treating the entire extract with formaldehyde, 10-ml. aliquots were employed.

The method was modified as follows: A 10-ml. aliquot was adjusted to pH 1.8 with 9.6 ml. of 6-percent metaphosphoric acid; 5.4 ml. of 37-percent formaldehyde was added to give a final formaldehyde concentration of 8 percent. After the required time interval, the reaction was stopped by the addition of 15 ml. of 25-percent metaphosphoric acid and the solution titrated within 1 minute. It was found in this procedure that for reaction times of 1 or more minutes, all the formaldehyde must be added within 6 seconds, while for reaction times of less than 1 minute, 3 seconds was the longest time allowable for addition of the formaldehyde.

Since the substances interfering with the determination of ascorbic acid in foods may consist of compounds other than reductones, iodine oxidation followed by hydrogen sulfide reduction for two different lengths of time was also tried. Tests were made for dihydroxymaleic acid (*52*) which likewise reacts similarly to ascorbic acid. The electrometric titration suggested by Wokes, Organ, and Jacoby (*72*) was tried but failed to differentiate interfering substances.

Thiamine was determined by the fluorophotometric method as described on page 7. In the fried potatoes, substances interfering with the measurement of thiamine were encountered. Their effect was at least partially eliminated by progressive dilution of the vitamin extracts until two successive aliquots gave concordant values for the vitamin. The retention values for thiamine did not give the satisfactory agreement found for the other nutrients.

Nicotinic acid was determined by microbiological assay (p. 7). Approximately 100- to 200-gm. samples were blended with 75 to 100 gm. of 0.15 N sulfuric acid in two or three macroblendors. Aliquots of 10 to 15 gm. of this mixture corresponding to 7 to 10 gm. of potato were weighed into Erlenmeyer flasks and were diluted with 100 ml. of the acid for subsequent autoclaving.

Moisture was determined in the Katahdin potatoes by drying to constant weight in an air oven at 100° C. In the other two varieties moisture was measured by an infrared lamp method (see Appendix A, p. 69). If the samples were to be ashed after determination of moisture, porcelain crucibles were used for both moisture and ash determinations.

Ash was determined on samples dried for moisture analysis, by incinerating to constant weight in a muffle furnace at 575° C. This required about 1½ hours.

Fat determinations were carried out on the samples of fried potatoes by extracting with ethyl ether in a Soxhlet apparatus.

Reproducibility of Analytical Values

Reproducibility of the analytical values obtained in this study is worth noting. The procedure of the American Association for Testing Materials for determining the limits of uncertainty (*2*) was used. The values are calculated for $P_S = 90$ based on six analyses for a single cooking process. The examples cited below are based on values for the ascorbic acid and ash contents for a given sample of Katahdin potatoes.

Ascorbic Acid Content (mg. per 100 gm. wet weight)

Raw potatoes, whole	11.07 ± 0.24; 8.4 ± 0.19; 7.06 ± 0.06
Raw potatoes, quartered	7.58 ± 0.13
Boiled potatoes, whole	8.59 ± 0.46; 6.62 ± 0.50
Boiled potatoes, quartered	8.55 ± 0.70; 5.85 ± 0.24; 4.85 ± 0.14

Ash Content (mg. per 100 gm. wet weight)

Raw potatoes, whole	957 ± 40
Boiled potatoes, whole	936 ± 50

Retention values based on these content figures are correspondingly of the same degree of reproducibility.

Results on Potatoes

Table 6 presents the moisture, ascorbic acid, ascorbic plus dehydroascorbic acid, thiamine, nicotinic acid, ash, and fat content per 100 gm. dry weight for the raw and drained cooked potatoes. Table 7 gives the values on the basis of wet weight. Table 8 presents retention of ascorbic acid, thiamine, nicotinic acid, ash, and solids for potatoes with and without cooking liquid.

Ascorbic acid content of the raw potatoes varied widely. The Katahdins, whole pared, averaged about 36 mg. ascorbic acid per 100 gm. dry weight as compared to 59 mg. for the Chippewas and 94 mg. for the Green Mountains.

Of the three varieties, Katahdin was the only one that showed the presence of dehydroascorbic acid in appreciable amounts before cooking. The Katahdins contained approximately 10 mg. of this constituent per 100 gm. dry weight. No evidence of the presence of protein-bound ascorbic acid or of dihydroxymaleic acid was obtained in any potato sample.

Thiamine in raw potatoes averaged about 0.49 mg. and 0.61 mg. for Green Mountain and Chippewa, respectively. Nicotinic acid in raw Katahdins averaged about 7.3 mg.

Ascorbic and Dehydroascorbic Acid

Storage.—Figure 1 illustrates the changes in ascorbic acid that occurred while the Katahdin potatoes were held in storage at 40° F. The ascorbic acid value was only half as great by the end of 3 months (Nov. to Jan.). During the latter part of the storage period (April and May) when the potatoes had begun to sprout, there was an increase in ascorbic acid content.

Potatoes withdrawn during the first week of storage and boiled whole unpared retained an average of 73 percent of their ascorbic acid as contrasted with 99 percent throughout the remainder of the storage period. This difference is probably not a sampling error because nicotinic acid and ash, the more stable nutrients, were practically completely retained (95 to 100 percent). It is possible that the loss of ascorbic acid in potatoes withdrawn during the very early period of storage may be due to changes in the enzyme system or may be related to lack of suberization (thickening of the potato skin and development of "corky" texture) (*4*, *5*).

It has been reported (*5*) that oxidase is present in larger quantities in potatoes at the end of the storage period than in new potatoes and that diastase remains active at all times during storage (*5*). If these enzyme systems were involved, retention of ascorbic acid would be expected to decrease slowly with storage time instead of remaining unchanged, as observed in the present experiments.

Appleman (*5*) showed that application of hydrogen peroxide to new potatoes resulted in penetration of the potato skins, retention of oxygen by the vegetable tissues, and finally sprouting. Older potatoes, in which suberization had started, similarly treated, were not affected. The degree of permeability of the potato skin varied with age (*22*, *23*). A difference in permeability such as Appleman demonstrated may account for the difference in the retention of ascorbic acid during the early as compared with the later parts of the storage period. Apparently the metabolic processes occurring during sprouting have no effect on the retention of nutrients in the cooked potato.

Related chemical factors.—It is evident from the data presented in tables 6, 8, and 9 that of the three varieties of potatoes studied, Katahdin was the only one which contained dehydroascorbic acid in appreciable amounts before cooking. Approximately 10 mg. per 100 gm. dry weight was present in these potatoes and this amount was affected but little by boiling, baking, cooking in a pressure saucepan, or mashing. Likewise, dehydroascorbic acid did not appear in more than traces in the Chippewa and Green Mountain potatoes when they were subjected to the same cooking procedures. However, ascorbic acid decreased in all three varieties during these cooking processes. It appears, therefore, that degradation of dehydroascorbic acid must have been taking place as rapidly as it was formed from ascorbic acid.

On the other hand, when boiled potatoes, whether pared or unpared, were held overnight, the ascorbic acid content decreased. At the same time, however, dehydroascorbic acid increased in amount relative to the ascorbic acid. This

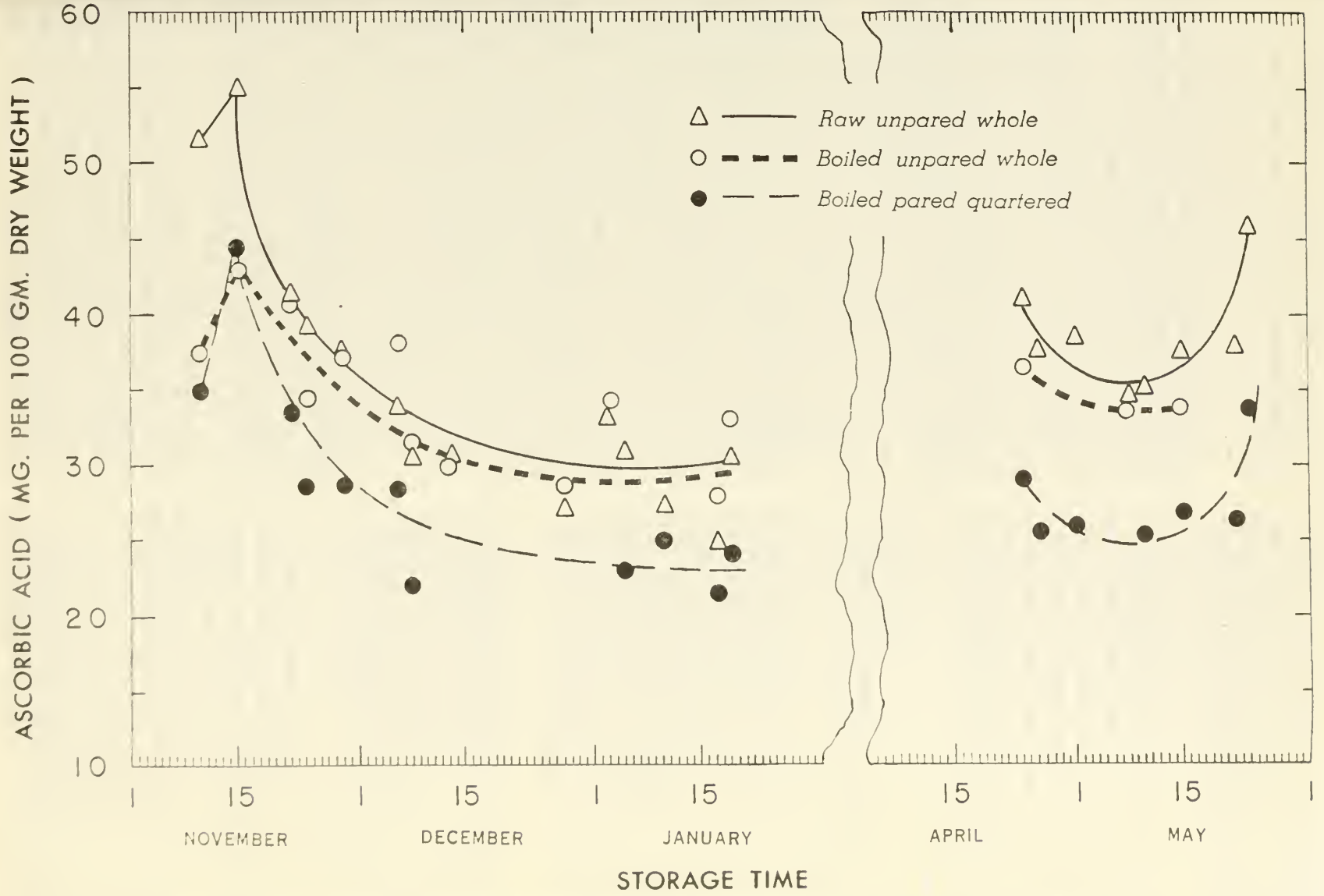

Figure 1.—Potatoes: Ascorbic acid content as affected by length of storage at 40° F. and reconditioning at 70° F.

may be interpreted as indicating that during holding, some ascorbic acid is transformed into dehydroascorbic acid, but for some reason as yet not understood, dehydroascorbic acid is stable under these conditions.

When the potatoes were hash-browned following holding, ascorbic acid was still further decreased in all but one case (Chippewa). The dehydroascorbic acid disappeared practically entirely, except in the case of the one sample of Chippewas which showed no decrease in ascorbic acid. This suggests that under the conditions of hash browning, dehydroascorbic acid is disappearing more rapidly than it is being formed from ascorbic acid.

In potatoes cooked in salted water, the salt appears to accelerate destruction of dehydroascorbic acid to an even greater degree than it does ascorbic acid.

Table 10 gives figures for retention of ascorbic acid before and after corrections have been applied for the presence of substances which react chemically in a manner similar to ascorbic acid. Tests for protein-bound ascorbic acid proved negative. Reductone-like substances were found when analyses were made according to a modification of Mapson's method (p. 32). Wokes' electrometric titration failed to differentiate them from ascorbic acid.

Interfering substances were found in French fries and country fries made from Chippewas. Since reductones are formed from glucose by heating in alkaline solutions and from sucrose by heating in neutral solutions, it is probable that heating, such as frying, results in the formation of reductones in potatoes containing glucose and sucrose.

Later it was observed that reductones developed slowly in the raw potatoes of this variety during the conditioning of the potatoes for frying. It is possible that the reductones were being formed from the reducing sugars and sucrose which decrease slowly when potatoes are stored at a higher temperature after first being exposed to low temperatures (*5*, *7*, *36*).

Increase in reductones with storage time, as in these experiments, might be an indication that potatoes exposed to variable storage temperatures undergo a more complex starch-sucrose-glucose transformation than has been recognized.

In determining the ascorbic acid value of potatoes or similar products which have been exposed to conditions favoring the formation of ascorbic acid-like substances, this possibility needs to be taken into consideration.

Boiling.—The three varieties of potatoes when boiled whole unpared showed on the average a high ascorbic acid retention of 94 percent without cooking liquid. Figures for Katahdin, Green Mountain, and Chippewa were 99, 90, and 91 percent, respectively. When dehydroascorbic acid was included, the corresponding figures for the three varieties were approximately the same, 95, 94, and 86 percent, respectively.

Boiled whole pared, Green Mountains and Chippewas showed a lower retention than the unpared; the figures were 69 and 79 percent, respectively. Corresponding figures for ascorbic acid plus dehydroascorbic acid were somewhat lower and more nearly alike—66 and 64 percent.

The Chippewas and Green Mountains, irrespective of the method of boiling, gave a range in pH of 6.0 to 6.3 in the residual liquid.

Boiled pared quartered potatoes showed about the same average retention of ascorbic acid and of ascorbic plus dehydroascorbic acid as did whole pared potatoes when considered with or without the cooking liquid (table 6). When pared, quartered, and boiled there was practically no difference among the three varieties.

The similar retention for pared whole and pared quartered potatoes is noteworthy. The quartered potatoes had 50 percent more surface exposed, but were cooked in 60 percent as much water and in approximately 60 percent of the time. Neither the whole nor quartered potatoes were covered completely with water throughout the cooking period.

Boiled in 350 ml. of water, pared quartered Katahdins retained 83 percent ascorbic acid, compared to 73 percent when cooked in 450 ml. of water. These figures are exclusive of residual cooking liquid and increase to 91 and 83 percent when the cooking liquid is included.

Although the cooking liquid contained approximately 10 percent of the original ascorbic acid in the potatoes, it lost this value when held overnight in the refrigerator.

Salting the water in which pared quartered Katahdin potatoes were cooked resulted in almost the same retention of ascorbic acid as boiling in the same quantity of unsalted water. The retention averaged 69 percent for the drained salted and 73 percent for the drained unsalted potatoes.

Soaking quartered Katahdins overnight in water to cover at room temperature and then boiling in fresh water resulted in about the same retention of ascorbic acid in the drained cooked potatoes, as did boiling unsoaked potatoes.

Holding boiled whole unpared potatoes overnight resulted in considerable loss of ascorbic acid. The method of cooling boiled unpared potatoes before holding in a refrigerator has important bearing on the ascorbic acid retained. The Katahdins were cooled to 77° F. in an ice bath about 1 hour and immediately placed in a refrigerator. The Green Mountains and Chippewas were allowed to cool to the same degree at room temperature for about 5 hours before being placed in the refrigerator. This difference in method of cooling probably accounts for the higher retention shown by Katahdins, 73 percent, as compared with 60 and 41 percent, shown by Green Mountain and Chippewa potatoes, respectively. The effect of holding boiled whole pared potatoes was similar, though the retention of ascorbic acid was somewhat lower.

Holding boiled potatoes, whether pared or unpared, showed an increase in dehydroascorbic acid and a corresponding decrease in ascorbic acid. This can be interpreted as indicating that during holding, some ascorbic acid is transformed into dehydroascorbic acid as was discussed earlier (p. 34, 36).

Hash browning boiled potatoes.—The ascorbic acid values are low because all hash-browned potatoes in these experiments were prepared from boiled potatoes that had been held overnight and had already lost appreciable amounts of their ascorbic acid. For hash-browned potatoes made from unpared and pared potatoes, the retention was as low as 40 and 24 percent, respectively. The hash-browning process alone destroyed about one-fourth of the ascorbic acid remaining in the cooked potatoes that were held overnight. The degree of destruction depends on the extent of browning.

Cooking in pressure saucepan.—Pared quartered potatoes cooked in a pressure saucepan for 8 minutes, excluding 2½ to 4½ minutes heating time, retained practically the same amount of ascorbic acid as those boiled in 350 ml. of water for 23 minutes. The pressure-cooked potatoes showed higher retention than those boiled in 450 ml. of water, both with respect to ascorbic acid alone and to ascorbic acid plus dehydroascorbic acid.

Mashing.—The ascorbic acid values of mashed potatoes varied with the value of the potatoes that were mashed. Mashed potatoes prepared from tubers boiled whole unpared showed high retention, 87 percent, of the ascorbic acid of the raw potato. The retention in mashed potatoes prepared from pressure-cooked quartered potatoes was 66 percent of the raw value; from boiled quartered pared potatoes, 52 percent; and from those boiled whole pared, 47 percent. Mashing alone, exclusive of boiling, caused destruction of 10 percent of the ascorbic acid present in cooked Katahdins.

Baking.—Baked whole unpared potatoes retained 75 percent ascorbic acid as compared with 94 percent for boiled whole unpared potatoes. Results were similar for the three varieties studied. When dehydroascorbic acid is considered, the retention is not consistent for the three varieties, Katahdin showing 102 percent, Green Mountain 72 percent, and Chippewa 80 percent.

Country frying.—When raw sliced potatoes (Green Mountain and Chippewa) were fried, retention of ascorbic acid was 62 percent and of ascorbic acid plus dehydroascorbic acid 55 percent.

French frying.—As a result of French frying, retention of 63 and 61 percent ascorbic acid was observed for Green Mountain and Chippewa potatoes, respectively. Corresponding retention of ascorbic acid plus dehydroascorbic acid was 59 and 66 percent.

Thiamine

Inconsistent results on thiamine retention were obtained. This was probably due to difficulty with the assay method as well as to variety and condition of the potatoes. Cooking methods ranked similarly for two varieties with respect to retention of thiamine, even though the absolute values differed.

For boiled or pressure-cooked potatoes analyzed without cooking liquid, average thiamine retention was relatively high. It was somewhat lower for baked and mashed; considerably lower for country fried and hash-browned; and lowest of all for French fried.

Nicotinic Acid

Nicotinic acid values showed some inconsistencies for unpared whole potatoes and their products. This was partially due to the fact that the analytical method used was accurate only within 20 percent and was affected adversely by the presence of starch.

In general, nicotinic acid retention was good for all cooking methods. For the pared quartered potatoes any nicotinic acid not retained in the drained cooked food was found to be in the cooking liquid.

Ash

Ash retention in general was consistent for the three varieties of potatoes and indicated that sampling was effective. In the case of some of the Chippewa potatoes retention was above 100 percent. Boiling and baking whole in the skin, also frying, showed high retention. Pressure cooking gave slightly lower retention. Pared quartered boiled potatoes gave still lower values as would be expected from increased surface exposure to the cooking liquid.

Summary and Conclusions on Potatoes

Three varieties of potatoes—Katahdin, Green Mountain, and Chippewa—purchased on the Washington, D. C., market were used. The nutritive value of potatoes raw and cooked by different common household methods such as boiling, baking, cooking in a pressure saucepan, and frying was investigated. Also in the case of Katahdins storage effects were observed.

The skin of the potato was extremely effective with respect to conservation of vitamins and ash. Potatoes boiled whole in their skins retained practically all of their ascorbic acid, ascorbic plus dehydroascorbic acid, thiamine, nicotinic acid, and ash.

When potatoes were pared, boiling resulted in 70- to 80-percent retention of ascorbic acid and somewhat more of the other nutrients in the drained cooked potato. The remainder of the thiamine, nicotinic acid, and ash of the raw potato was in the cooking liquid. Only about one-half the ascorbic acid unaccounted for in the drained potato was in the cooking liquid.

Quartering in addition to paring potatoes had little over-all effect on retention of nutrients. Boiling pared quartered potatoes resulted in only slightly less retention of the nutrients than boiling whole, pared. This was due perhaps to the shorter cooking time and smaller quantity of water, which appeared to offset the loss from greater surface area exposed.

The volume of cooking water also affected the retention of nutrients. The boiled quartered potatoes reported above were cooked in just enough water to cover. When potatoes were cooked in about three-fourths as much water, retention of ascorbic acid was about 10 percent greater.

Although neither soaking nor boiling potatoes in salted water under the conditions of this experiment had unfavorable results, more research is needed before general conclusions can be drawn.

Holding boiled potatoes overnight in the refrigerator affected only ascorbic acid of the nutrients studied. Potatoes cooked and held in their skins retained more ascorbic acid than those pared, cooked, and held.

Cooking in a pressure saucepan was carried out only on pared quartered potatoes. These retained about 80 percent of ascorbic acid, with practically no change in the other nutrients.

Mashing itself had only a slight effect on the nutrients studied. Most important was the method of cooking. Mashed potatoes made from those freshly boiled whole in their skins retained

most of their nutritive value. But the result was quite different when pared quartered potatoes were used.

Baking potatoes whole in their skins is in general a good method of conserving nutrients. Retention of ascorbic acid, nicotinic acid, and ash was similar to that in pared quartered potatoes cooked in a pressure saucepan, but not so good as in those boiled whole in their skins. Approximately 70 percent of the thiamine was retained in baked potatoes as compared with about 85 percent in those boiled whole in skins.

Hash browning, like mashing, is an additional treatment of the cooked potatoes and results in further destruction of ascorbic acid and thiamine. The destruction of ascorbic acid in hash browning was greater than in mashing potatoes, because it involves a second heating. Loss of thiamine was also marked.

Two methods of frying raw potatoes were studied: Country frying and French frying. The methods resulted in about 60-percent retention of ascorbic acid. Thiamine retention was markedly affected.

Table 5.—Potatoes: ***Preparation and home cooking procedures, yield of product, and residual liquid***

Cooking method	Identification No. [1]	Size of raw sample (edible portion)	Water used in cooking	Ratio of potato to water	Cooking time	Fat	Cooked yield	Residual cooking liquid
		Gm.	*Ml.*	*Gm. per ml.*	*Min.*	*Gm.*	*Gm.*	*Ml.*
Unpared:								
Whole:								
Boiled covered [2]	3	680	750	0.91	40		669	357
Hash-browned after holding overnight [3]	3c	[4]680			15	[5]27	533	
Hash-browned after holding overnight [6]	3d	[4]680			24	[7]53	413	
Baked [2]	4	680			45		561	
Pared:								
Whole:								
Boiled covered [6]	5	680	750		40		666	506
Hash-browned after holding overnight [6]	5c	[4]680			25	[7]53	408	
Quartered:								
Boiled covered [2]	6	680	450	1.51	23		660	274
Boiled covered, 4.5 gm. salt added [3]	7	680	450	1.51	23		660	274
Boiled covered [3]	8	680	350	1.94	23		651	218
Cooked in pressure saucepan [8]	10	680	[9]80	8.50	8		640	[9]29
Sliced:								
Country fried [6]	11	680			31	[7]68	358	
French fried [6]	12	680			11	[7]2,040	250	

[1] All samples, raw and cooked, are numbered. Only those for cooked samples appear in this table.
[2] Method for Katahdin, Green Mountain, and Chippewa.
[3] Method for Katahdin.
[4] Size of boiled sample.
[5] Hydrogenated cottonseed oil.
[6] Method for Green Mountain and Chippewa.
[7] Peanut oil.
[8] Method for Katahdin and Green Mountain.
[9] Below rack, not in direct contact with food.

Table 6.—Potatoes: ***Vitamin and ash content*** [1] ***per 100 grams dry weight, as affected by various home cooking procedures***

Cooking method [2]	Identification No.	Number of samples [3]			Moisture			Ascorbic acid		
		Katahdin	Green Mountain	Chippewa	Katahdin	Green Mountain	Chippewa	Katahdin	Green Mountain	Chippewa
					Pct.	*Pct.*	*Pct.*	*Mg.*	*Mg.*	*Mg.*
Raw:										
Pared:										
Whole	1	[4]16	2	1	80.8	81.4	81.4	35.5	94.0	59.4
Quartered	2	18			81.4			38.1		
Cooked:										
Unpared:										
Whole:										
Boiled covered, 40 min., 750 ml. water [5]	3	[4]16	2	1	80.9	80.0	81.2	34.7	82.5	54.2
Mashed	3a	2			82.1			29.2		
Held overnight [5]	3b	2	2	1	80.2	80.1	80.0	22.2	55.2	23.1
Hash-browned after holding overnight	3c, 3d	2	3	2	72.1	57.0	53.7	16.1	30.0	15.9
Baked [5]	4	2	2	1	76.8	76.7	78.4	27.2	64.3	38.9
Pared:										
Whole:										
Boiled covered, 40 min., 750 ml. water	5		2	1		80.4	79.7		63.3	38.3
Mashed	5a		2	1		80.3	79.7		44.5	26.6
Held overnight	5b		2	1		79.9	79.8		32.8	17.8
Hash-browned after holding overnight	5c		4	2		54.2	52.6		16.7	9.63
Quartered:										
Boiled covered, 23 min., 450 ml. water	6	18	2	1	81.4	79.7	81.6	28.3	64.6	41.7
Mashed	6a		2	1		79.8	79.7		48.2	29.8
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	2			80.0			28.8		
Boiled covered, 23 min., 350 ml. water	8	2			81.0			23.0		
Boiled covered, 23 min., 450 ml. water, after soaking overnight.	9	1			83.5			25.2		
Cooked in pressure saucepan, 8 min.	10	3	2		80.5	79.5		28.1	71.0	
Mashed	10a		2			79.4			61.6	
Sliced:										
Country fried	11		4	[6]3		45.2	49.7		40.1	[7]22.6
French fried	12		2	4		32.3	23.3		43.8	[7]20.1

Cooking method [2]	Identification No.	Ascorbic plus dehydroascorbic acid			Thiamine		Nicotinic acid	Ash			Fat	
		Katahdin	Green Mountain	Chippewa	Green Mountain	Chippewa	Katahdin	Katahdin	Green Mountain	Chippewa	Green Mountain	Chippewa
		Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Pct.*	*Pct.*
Raw:												
Pared:												
Whole	1	45.0	96.8	59.9	0.486	0.613	7.32	5,300	4,665	4,120		
Quartered	2	49.5					7.06	5,490				
Cooked:												
Unpared:												
Whole:												
Boiled covered, 40 min., 750 ml. water [5]	3	44.9	76.3	51.3	.422	.473	7.98	5,330	4,480	3,960		
Mashed	3a	38.7					8.51	5,650				
Held overnight [5]	3b	37.8	67.4	29.4	.400	.418	8.80	5,130	4,420	3,990		
Hash-browned after holding overnight	3c, 3d	19.4	30.4	12.7	.185		7.68	4,720	2,770	3,000	25.0	25.7
Baked [5]	4	43.4	67.4	41.1	.365	.372	7.62	6,340	4,450	4,270		
Pared:												
Whole:												
Boiled covered, 40 min., 750 ml. water	5		62.8	31.2	.450	.468			3,740	3,370		
Mashed	5a		49.2	28.3	.421	.400			3,670	3,130		
Held overnight	5b		53.2	21.7	.382	.574			3,660	3,620		
Hash-browned after holding overnight	5c		17.2	8.8	.162	.161			2,120	2,235	25.9	23.6
Quartered:												
Boiled covered, 23 min., 450 ml. water	6	41.8	69.1	38.9	.408	.598	6.61	4,510	3,430	3,260		
Mashed	6a		54.4	28.9	.372	.438			3,310	3,220		
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	33.0					5.34	6,340				
Boiled covered, 23 min., 350 ml. water	8	28.5					7.46	4,300				
Boiled covered, 23 min., 450 ml. water, after soaking overnight.	9	52.5					7.27	4,610				
Cooked in pressure saucepan, 8 min.	10	46.8	78.8		.506		8.59	5,630	4,150			
Mashed	10a		69.7		.438				4,260			
Sliced:												
Country fried	11		35.8		.101	.273			2,560	3,310	27.0	26.6
French fried	12		40.9	27.2	.114	.079			3,370	2,660	22.9	29.7

[1] Values for cooked potatoes based on drained weight.
[2] See table 5 for details of cooking methods.
[3] Each sample represents 3 replicate cooked portions for the Katahdin potatoes, but a single cooked portion for each of the other varieties.
[4] Only 14 samples were used for determining ascorbic acid alone and ascorbic plus dehydroascorbic acid.
[5] Analyzed peeled.
[6] 3 samples were analyzed for ascorbic acid but only one was successfully corrected for interfering substances.
[7] Corrected for interfering substances.

Table 7.—Potatoes: *Vitamin and ash content* [1] *per 100 grams wet weight, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Number of samples [3]			Moisture			Ascorbic acid		
		Katahdin	Green Mountain	Chippewa	Katahdin	Green Mountain	Chippewa	Katahdin	Green Mountain	Chippewa
					Pct.	*Pct.*	*Pct.*	*Mg.*	*Mg.*	*Mg.*
Raw:										
Pared:										
Whole	1	[4]16	2	1	80.8	81.4	81.4	6.8	17.5	11.0
Quartered	2	18			81.4			7.1		
Cooked:										
Unpared:										
Whole:										
Boiled covered, 40 min., 750 ml. water [5]	3	[4]16	2	1	80.9	80.0	81.2	6.6	16.5	10.2
Mashed	3a	2			82.1			5.2		
Held overnight [5]	3b	2	2	1	80.2	80.1	80.0	4.4	11.0	4.6
Hash-browned after holding overnight	3c, 3d	2	3	2	72.1	57.0	53.7	4.5	12.9	7.4
Baked [5]	4	2	2	1	76.8	76.7	78.4	6.3	15.0	8.4
Pared:										
Whole:										
Boiled covered, 40 min., 750 ml. water	5		2	1		80.4	79.7		12.4	7.8
Mashed	5a		2	1		80.3	79.7		8.8	5.4
Held overnight	5b		2	1		79.9	79.8		6.6	3.6
Hash-browned after holding overnight	5c		4	2		54.2	52.6		7.6	4.6
Quartered:										
Boiled covered, 23 min., 450 ml. water	6	18	2	1	81.4	79.7	81.6	5.3	13.1	7.7
Mashed	6a		2	1		79.8	79.7		9.7	6.0
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	2			80.0			5.8		
Boiled covered, 23 min., 350 ml. water	8	2			81.0			4.4		
Boiled covered, 23 min., 450 ml. water, after soaking overnight.	9	1			83.5			4.2		
Cooked in pressure saucepan, 8 min.	10	3	2		80.5	79.5		5.5	14.6	
Mashed	10a		2			79.4			12.7	
Sliced:										
Country fried	11		4	[6]3		45.2	49.7		22.0	[7]11.4
French fried	12		2	4		32.3	23.3		29.7	[7]15.4

Cooking method [2]	Identification No.	Ascorbic plus dehydroascorbic acid			Thiamine		Nicotinic acid	Ash			Fat	
		Katahdin	Green Mountain	Chippewa	Green Mountain	Chippewa	Katahdin	Katahdin	Green Mountain	Chippewa	Green Mountain	Chippewa
		Mg.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Pct.*	*Pct.*
Raw:												
Pared:												
Whole	1	8.6	18.0	11.1	0.090	0.114	1.40	1,018	868	766		
Quartered	2	9.2					1.31	1,021				
Cooked:												
Unpared:												
Whole:												
Boiled covered, 40 min., 750 ml. water [5]	3	8.6	15.3	9.6	.084	.089	1.52	1,018	896	744		
Mashed	3a	6.9					1.52	1,011				
Held overnight [5]	3b	7.5	13.4	5.9	.080	.084	1.74	1,016	880	798		
Hash-browned after holding overnight	3c, 3d	5.4	13.1	5.9	.080		2.14	1,317	1,191	1,389	10.8	11.9
Baked [5]	4	10.1	15.7	8.9	.085	.084	1.77	1,471	1,037	922		
Pared:												
Whole:												
Boiled covered, 40 min., 750 ml. water	5		12.3	6.3	.088	.095			733	684		
Mashed	5a		9.7	5.7	.083	.081			723	635		
Held overnight	5b		10.7	4.4	.077	.116			736	731		
Hash-browned after holding overnight	5c		7.9	4.2	.074	.076			971	1,059	11.9	11.2
Quartered:												
Boiled covered, 23 min., 450 ml. water	6	7.8	14.0	7.2	.083	.110	1.23	839	696	600		
Mashed	6a		11.0	5.9	.075	.089			669	654		
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	6.6					1.07	1,268				
Boiled covered, 23 min., 350 ml. water	8	5.4					1.42	817				
Boiled covered, 23 min., 450 ml. water, after soaking overnight.	9	8.7					1.20	761				
Cooked in pressure saucepan, 8 min	10	9.1	16.2		.104		1.68	1,098	851			
Mashed	10a		14.4		.090				878			
Sliced:												
Country fried	11		19.6		.055	.137			1,403	1,665	14.8	13.4
French fried	12		27.7	20.9	.077	.060			2,281	2,040	15.5	22.8

[1] Values for cooked potatoes based on drained weight.
[2] See table 5 for details of cooking methods.
[3] Each sample represents 3 replicate cooked portions for the Katahdin potatoes, but a single cooked portion for each of the other varieties.
[4] Only 14 samples were used for determining ascorbic acid alone and ascorbic plus dehydroascorbic acid.
[5] Analyzed peeled.
[6] 3 samples were analyzed for ascorbic acid but only one was successfully corrected for interfering substances.
[7] Corrected for interfering substances.

Table 8.—Potatoes: *Retention [1] of vitamins and ash, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Ascorbic acid				Thiamine			Nicotinic acid	Ash				Solids		
		Katahdin	Green Mountain	Chippewa	Average	Green Mountain	Chippewa	Average	Katahdin	Katahdin	Green Mountain	Chippewa	Average	Katahdin	Green Mountain	Chippewa
		DRAINED POTATOES														
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Unpared:																
Whole:																
Boiled covered, 40 min., 750 ml. water	3	99.4	90.3	91.4	93.7	91.5	77.2	84.4	105.9	97.9	100.3	96.4	98.2			
Mashed	3a	87.2							104.2	96.4						
Held overnight [3]	3b	73.4	59.8	40.5		83.7	71.0	77.3	119.0	94.3	96.0	101.0	97.1			
Hash-browned after holding overnight [3].	3c, 3d	60.4	42.6	39.6		51.0			113.4	100.4	78.8	113.1	97.4			
Baked	4	77.4	70.2	76.1	74.6	76.6	65.2	70.9	109.3	107.4	97.7	102.9	102.7			
Pared:																
Whole:																
Boiled covered, 40 min., 750 ml. water	5		68.7	79.2	74.0	95.2	86.6	90.9			81.8	85.9	83.8			
Mashed	5a		47.1	47.0	47.0	87.6	68.7	78.1			79.0	80.1	79.5			
Held overnight [3]	5b		35.1	35.1	35.1	79.2	101.0	90.1			78.4	90.2	84.3			
Hash-browned after holding overnight [3].	5c		24.3	27.2	25.7	45.4	40.4	42.9			87.2	77.5	82.4			
Quartered:																
Boiled covered, 23 min., 450 ml. water	6	72.5	71.2	67.8	70.5	88.3	94.0	91.2	83.1	80.2	76.3	76.2	77.6			
Mashed	6a		52.2	52.7	52.4	79.0	75.0	77.0			72.5	82.0	77.2			
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	68.6							86.0	69.0						
Boiled covered, 23 min., 350 ml. water	8	83.0							83.8	85.0						
Boiled covered, 23 min., 450 ml. water, after soaking overnight.	9	71.7							92.2	78.3						
Cooked in pressure saucepan, 8 min	10	80.8	77.3		79.0	107.7			98.7	92.5	91.1		91.8			
Mashed	10a		66.1			92.2					92.4					
Sliced:																
Country fried	11		63.2	[4]61.1	62.2	30.3	68.5	49.4			105.7	111.3	108.5			
French fried	12		62.5	[4]60.9	61.7	34.6	21.8	28.2			99.1	88.2	93.6			
		POTATOES PLUS COOKING LIQUID														
Unpared:																
Whole:																
Boiled covered, 40 min., 750 ml. water	3	99.9	90.8	91.4		91.5	77.2		111.5	102.5	103.5	111.9		99.2	106.6	102.5
Pared:																
Whole:																
Boiled covered, 40 min., 750 ml. water	5		77.7	87.4		111.8	99.9				101.4	103.3			105.3	114.7
Quartered:																
Boiled covered, 23 min., 450 ml. water	6	83.2	84.1	76.4		105.2	111.0		101.5	100.6	96.6	98.3		101.3	107.2	99.7
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	76.8							101.8	101.4				103.6		
Boiled covered, 23 min., 350 ml. water	8	91.0							100.1	93.6				103.8		
Cooked in pressure saucepan, 8 min	10	82.3	79.8			108.0			101.3	92.3	96.4			99.6	103.6	

[1] Retention is calculated as follows: $\frac{\text{content per gm. cooked} \times \text{cooked weight (gm.)}}{\text{content per gm. raw} \times \text{raw weight (gm.)}} \times 100$.

[2] See table 5 for details of cooking methods.

[3] Katahdins cooled immediately in an ice bath and then held in refrigerator; Green Mountains and Chippewas cooled at room temperature and then held in refrigerator.

[4] Corrected for interfering substances (table 10).

Table 9.—Potatoes: ***Retention*** [1] ***of ascorbic acid and of ascorbic plus dehydroascorbic acid, as affected by various home cooking procedures***

Cooking method [2]	Identification No.	Ascorbic acid			Ascorbic plus dehydroascorbic acid		
		Katahdin	Green Mountain	Chippewa	Katahdin	Green Mountain	Chippewa
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Unpared:							
Whole:							
Boiled covered, 40 min., 750 ml. water	3	99.4	90.3	91.4	94.6	93.5	85.6
Mashed	3a	87.2			81.7		
Held overnight	3b	73.4	59.8	40.5	102.8	70.2	51.2
Hash-browned after holding overnight	3c, 3d	60.4	42.6	39.6	60.2	41.6	31.4
Baked	4	77.4	70.2	76.1	101.6	71.6	79.5
Pared:							
Whole:							
Boiled covered, 40 min., 750 ml. water	5		68.7	79.2		66.1	63.8
Mashed	5a		47.1	47.0		50.7	49.7
Held overnight	5b		35.1	35.1		55.1	43.2
Hash-browned after holding overnight	5c		24.3	27.2		24.4	24.6
Quartered:							
Boiled covered, 23 min., 450 ml. water	6	72.5	71.2	67.8	78.1	74.0	62.5
Mashed	6a		52.2	52.7		57.4	50.5
Boiled covered, 23 min., 450 ml. water, 4.5 gm. salt added.	7	68.6			63.0		
Boiled covered, 23 min., 350 ml. water	8	83.0			71.2		
Boiled covered, 23 min., 450 ml. water, after soaking overnight.	9	71.7			65.0		
Cooked in pressure saucepan, 8 min.	10	80.8	77.3		82.4	83.4	
Mashed	10a		66.1			72.8	
Sliced:							
Country fried	11		63.2	[3]61.1		54.8	
French fried	12		62.5	[3]60.9		59.3	66.3

[1] Retention is calculated on the basis of the drained food, as follows: $\frac{\text{content per gm. cooked} \times \text{cooked weight (gm.)}}{\text{content per gm. raw} \times \text{raw weight (gm.)}} \times 100$.

[2] See table 5 for details of cooking method.

[3] Corrected for interfering substances (table 10).

Table 10.—Potatoes: ***Effect of interfering substances on retention of ascorbic acid during frying***

Cooking method and storage condition of potatoes prior to cooking	Identification No.	Retention of ascorbic acid		
		Green Mountain	Chippewa	
		Free of interfering substances	With interfering substances present	Corrected for interfering substances
		Percent	*Percent*	*Percent*
Country fried:				
10 days (av.) at 70° F.	11	63.2		
8 days at 70° F.	11		87.5	[1]61.1
French fried:				
5 days (av.) at 70° F.	12	62.5		
6 days at 70° F.	12		97.4	Not determined
17 days at 70° F.	12		102.9	[1]59.1
24 days at 70° F.	12		113.4	[2]56.9
36 days at 70° F.	12		57.4	[2]60.7

[1] Interfering substances (reductone-like) present in cooked sample only.

[2] Interfering substances present in raw and cooked samples.

[3] Interfering substances present in raw and cooked samples, but proportionately higher in raw.

CARROTS

Carrots, like potatoes, are produced abundantly all over the United States. They are used extensively the year around. Most important nutritive value contributed by carrots is carotene, precursor of vitamin A. In the course of a recent analysis of the national food supply from 1909 to 1945 (*17*), inclusive, it was found that carrots provided about 16 percent of the total vitamin A value and 5 percent of the ascorbic acid of food as brought into the kitchen.

An investigation of the effect of different methods of home preparation on the nutritive value of carrots was therefore undertaken. Home preparation included not only cooking but also preparing carrots in raw forms frequently served for salad. In the study of cooked carrots, analyses were made for carotene, ascorbic acid, dehydroascorbic acid, nicotinic acid, moisture, and ash. In those studied raw, ascorbic acid, dehydroascorbic acid, moisture, and ash were determined.

Variety and Storage

Two varieties of carrots, Chantenay and Imperator, were used in these studies. Chantenays from Pennsylvania were available when purchase was made on the Washington, D. C., market for the first cooking study. These were mature carrots without tops and enough were purchased in one lot for the whole study. To assure uniformity, only those weighing from 100 to 200 gm. and measuring 3 inches or more in length and 1½ to 2½ inches in diameter at the top were selected. They were placed in storage at 32° F. and 85 percent relative humidity on Feb. 7, 1944. Analyses were made between Feb. 15 and May 15.

During the cooking study, quantities of Chantenays sufficient for a week's analyses were removed from storage at one time and placed in a walk-in refrigerator at 40° F. Forty-eight hours before an experiment was started, the carrots to be used were placed in a compartment held at 50° F. and kept there until withdrawn for the experiment. At that time, the carrots were brought to the laboratory, washed in distilled water, divided into two batches, one for cooking and one to be analyzed raw, and held 18 to 42 hours at room temperature.

From December 1945 to March 1946, cooking studies were repeated on young Imperators purchased on the Washington, D. C., market. The results are not reported because of interfering substances in determination of ascorbic acid (see p. 49).

For the studies of raw carrots the Imperator variety was bought on the Washington, D. C., market in 14 successive lots during May and June 1945. These were young carrots, California grown, with tops removed at the time of purchase. Within a lot they varied from 4 to 8 inches in length and from 1 to 2 inches in top diameter. After delivery they were held at 40° F. and used within 48 hours.

Preparation, Cooking, Sampling

Control of Cooking Conditions

Cooking methods were boiling, steaming, and cooking in a pressure saucepan. The carrots were cooked unpared whole, pared whole, quartered lengthwise and sliced crosswise. Details of preparation, method of cutting and cooking, weight of raw and cooked food, volume of water and residual liquid, and cooking time, are presented in table 11.

Carrots were prepared in portions to approximate 680 gm. each—a quantity sufficient to provide six common household servings. Each method of preparation was carried out in triplicate. The number of replications of each experiment is given with the analytical results.

The cooking equipment, i.e., the utensils and stoves, were the same as those used for corresponding procedures in the potato study (p. 30).

The end point in cooking the carrots was determined in preliminary experiments by the puncture test and by tasting. In all cases, the carrots were cooked until just tender. The time required varied with the size of pieces and method of cooking.

Parallel with the nutritive-value tests, palatability evaluations were made on the cooked carrots by a panel of five housewives. The carrots, including those cooked whole, were served either quartered or sliced crosswise in ¼-inch slices. The characteristics scored included appearance, intensity of carrot flavor, sweetness, texture, and general acceptability.

Boiling.—Unpared and pared whole carrots, and pared carrots either quartered lengthwise or sliced crosswise were boiled in 3-quart covered enameled pans. Salted or unsalted distilled water was boiled 3 minutes before the vegetable was added. The quantity of water used for most of the experiments was less than enough to cover the carrots but sufficient to prevent scorching.

Steaming.—Pared quartered carrots were placed in the perforated upper section of a 6-quart household aluminum steamer. The bottom section contained 2,000 ml. of rapidly boiling water.

Cooking in pressure saucepan.—The pared mature carrots sliced crosswise were cooked at 15 pounds pressure in a 3-quart aluminum pressure saucepan for 4 minutes. Besides the 4 minutes, there was a heating time of 3 to 4½ minutes which included 1 minute for escape of air and steam. As soon as the cooking was completed, the saucepan was placed in cold water which caused the pressure to drop to zero within 30 seconds.

Serving raw.—Carrots for serving raw were pared and quartered, then cut into strips or shredded into three different shapes or sizes. The factors considered in the experiments on these raw carrots were: Surface area exposed, length of holding time after preparation, and composition of the kitchen cutlery used.

The cutlery was that obtainable during wartime. Stainless steel or plastic knives were used for cutting the carrots longitudinally into eighths. The resulting strips varied with the size of the carrot.

A tin-plated shredder, with a cutting edge ½ inch long, produced wedges not more than ½ inch long and ¼ inch at the thickest part. Another tin-plated shredder formed shreds not more than ⅛ inch in diameter and ½ inch long. A plastic grater with teeth set approximately ⅛ inch apart produced gratings about ⅛ inch or less square and about 1/25 inch thick.

A uniform holding time of 1 hour was adopted for comparing the various cuts. In addition, tests were made on the shreds for stability of ascorbic acid and dehydroascorbic acid immediately after shredding and after holding 1, 3, and 5 hours, respectively.

Sampling Methods

Three approximately 680-gm. portions of raw or cooked carrots for any given method were composited to permit adequate sampling for the chemical analyses. Blendors were used for homogenizing a sample. The contents of three or four blendors were composited and aliquots were withdrawn for analysis.

For cooking.—The whole carrots were divided at random into portions consisting of equal numbers, one portion for the raw sample and one for each of the cooked samples. The carrots cooked whole and those to be studied raw were pared immediately before analysis. After cooking they were quartered longitudinally, one quarter from every carrot being included in the sample set aside for each nutrient. Cutting from top to tip along the long axis retained the normal ratio of core to outer portion.

In the case of carrots cooked quartered, opposite quarters of the carrots were dealt into two portions, one for the raw and one for the cooked samples. Both the raw and cooked quarters, as in the case of quartered potatoes, were further subsampled to provide the samples for analysis of each nutrient.

In the case of the carrots sliced crosswise, alternate slices of pared carrots were taken for the raw and the cooked samples. Care was taken to distribute equally slices from different parts of the carrot. The slices, raw and cooked, from each of these batches were spread on trays and removed at random by spoonfuls. They were further divided by withdrawing a quarter from each slice for analysis of each nutrient.

For serving raw.—A quarter was withdrawn from every carrot for the samples to be analyzed

immediately, to give a base value. Only center longitudinal slices from a quarter were used for ascorbic acid. The remaining quarters from each carrot were used for strips, wedges, shreds, or gratings. The plan for sampling strips was similar to that for quartered potatoes (p. 31). Samples for the other forms were removed at random. Two or three of these forms were studied in parallel on any one day.

Methods of Analysis

In general the analytical methods were the same as those used in the experiments on the 20 foods (p. 6) and on potatoes (p. 32). However, for ascorbic acid 6-percent instead of 3-percent metaphosphoric acid was used as the extracting medium.

In the case of ascorbic acid, difficulties were sometimes encountered in determining the visual end point. Some of the pigment of the carrots, particularly in certain batches of the cooked vegetable, was extracted during blending with the metaphosphoric acid. This pigment was found to be soluble in petroleum ether (fraction boiling 30° to 60° C.).

In these cases, an aliquot of the acid extract was treated with successive portions of petroleum ether in a separatory funnel until all the pigment had been extracted. The combined petroleum ether layers were washed with 6-percent metaphosphoric acid and the acid washings added to the colorless extracted solution, which was then titrated visually. Comparison of ascorbic acid values from such extracted aliquots with values obtained by electrometric titrations showed no loss of ascorbic acid. One or two aliquots from each sample were tested routinely to determine whether or not this procedure was necessary for obtaining correct values.

Carotene was determined on both raw and cooked carrots by the method described on page 7. These values were determined chemically by chromatographing petroleum ether extracts of the carrots. Magnesium oxide was the first adsorbent employed for separating alpha- and beta-carotene (precursors of vitamin A) from inactive pigments (*75*). Alpha- and beta-carotene recoveries calculated from these analyses were variable. For comparison of the total alpha-beta recovery dicalcium phosphate was substituted for magnesium oxide as an adsorbent in an effort to account for the discrepancy. However, the sum of the alpha- and beta-carotene values for the two adsorbents agreed well when correction was made for differences in percent recovery from the chromatographing columns. This showed that the method of separating the carotene was probably not at fault.

Results on Carrots

Cooked Carrots

For the cooked carrots the content per 100 gm. dry weight for all nutrients studied is given in table 12. Values for wet weight are given in table 13. Retention of nutrients, except carotene, in drained carrots and in carrots plus cooking liquid is given in table 14.

Carotene.—Since there was not always good agreement in carotene analyses, average instead of individual values are reported. The average beta-carotene value for raw carrots was about 70 mg. and for cooked, 72 mg. per 100 gm. dry weight, with a range from 50 to 92 mg.

The highest coefficient of variation found in a single cooked portion was 18.3 and the lowest 1.6. These extremes of variability were apparently not caused by enzyme action in the raw carrots, since tests with potassium cyanide failed to give higher values. Good representative sampling was extremely difficult, due to the great difference in concentration of carotene in the cortex and phloem of the root. Larger samples for analysis than it was possible to obtain under the conditions of these experiments would no doubt have largely compensated for the uneven distribution of carotene in the carrots.

Ascorbic acid.—The average ascorbic acid values ranged from 30 to 38 mg. dry weight for the various raw samples. Ascorbic acid content of carrots, unlike that of potatoes, was unaffected by storage for 2 months, though the carrots were less acceptable in flavor and texture when cooked.

Boiling affected the ascorbic acid content of whole carrots similarly whether boiled pared or unpared. Moreover, retention of ascorbic acid

was high whether the unpared whole carrots were boiled in enough water to cover (800 ml.), or in one-half that amount. In all these cases retention of ascorbic acid was about 90 percent for drained carrots.

Ascorbic acid retention in pared quartered carrots without cooking liquid was about 60 percent when the carrots were cooked in water to cover, and about 80 percent when cooked in half that quantity. Boiling carrots sliced crosswise in a relatively small quantity of water retained 70 percent ascorbic acid. Only a small amount of ascorbic acid (2 to 5 percent) was found in the residual liquid from each method of cooking. This indicates that the losses are due largely to heat and oxidation.

Addition of salt to the cooking water for whole carrots pared and unpared resulted in ascorbic acid retention similar to that for unsalted carrots. Addition of salt for carrots quartered or sliced crosswise caused somewhat lower retention of the vitamin than for corresponding unsalted pieces.

Steaming of pared quartered carrots gave retention of ascorbic acid similar to that for carrots boiled in one-half the quantity of water needed to cover.

Use of a pressure saucepan in cooking crosswise slices gave higher retention of ascorbic acid than boiling carrots cut this way. With a pressure cooking time of 4 minutes at 15 pounds, plus a heating time of 3 to 4½ minutes, the retention of ascorbic acid was 89 percent. The retention was practically as high as for carrots boiled whole.

When cooking time, as well as cut, is considered in relation to ascorbic acid, retention was better in the carrots cooked whole 40 minutes than in the crosswise slices cooked 18 minutes. The figures were about 90 and 70 percent, respectively. Presumably this is due to the exposure of one-third to one-half as much cut surface per carrot pared whole as per carrot sliced crosswise.

In both raw and cooked carrots 5 to 15 mg. of dehydroascorbic acid was present. In the case of unpared whole carrots, the retention of ascorbic plus dehydroascorbic acid was the same as for ascorbic acid alone. With increased exposure of surface to air and water, however, the difference in retention between ascorbic acid and ascorbic plus dehydroascorbic acid increased. This showed that ascorbic acid was changing to dehydroascorbic acid faster than dehydroascorbic acid was being destroyed.

From December 1945 to March 1946, studies on immature Imperator carrots showed reductones in both the raw and cooked state. A satisfactory chemical method which would correct for these substances and give reproducible retention was not developed at the time. (See p. 32.) For this reason, these results are not reported. Tests indicated, however, that the interfering substances were not protein-bound ascorbic acid. (See p. 32.)

Nicotinic acid.—Average nicotinic acid values ranged from 5 to 8 mg. dry weight for the various raw samples. This vitamin was practically all retained in boiled carrots plus residual liquid. Retention was lower when quartered carrots were cooked in 600 ml. of water and the cooking liquid discarded than when the same weight of carrots was cooked in 300 ml. of water. The presence of salt did not appear to change the effect of cooking water upon retention of nicotinic acid except possibly in the case of carrots sliced crosswise.

Ash.—The percentage of ash retained was comparable to nicotinic acid under various cooking conditions except where salt was used. The presence of salt in the water resulted in greater loss of mineral matter from the carrots.

Ash retention did not change appreciably in cases where solubility was a negligible factor as in cooking in a pressure saucepan. Drained carrots sliced lengthwise in quarters retained about as much as those sliced crosswise; and quarters boiled in the smaller quantity of water retained more than those boiled in the larger quantity.

Carrots Prepared for Serving Raw

These studies were confined to ascorbic acid, the vitamin most affected by preparation methods, and to ash, a stable nutrient which served as a check on sampling. The results on a dry-weight basis are given in table 15, and on a wet-weight basis in table 16.

Although the carrots were all of Imperator variety grown in the same State and bought within 2 months time, they showed great variation from lot to lot in their content of both ascorbic acid and ash.

The average ash content of carrots prepared for serving raw was 6,700 mg. per 100 gm. dry weight, with a range of 5,870 to 8,130 mg. Retention of ash was high, 97 to 103 percent throughout, which indicated successful sampling.

The average ascorbic acid value was 44 mg. per 100 gm. dry weight, with a range of 31 to 56 mg. The average for ascorbic plus dehydroascorbic acid was 52 mg. per 100 gm. dry weight, with a range of 30 to 73 mg. Reductones were not found in these young carrots.

Surface area as it varies with size and shape of pieces is important in relation to ascorbic acid retention, as shown in table 15. As the surface area was increased, retention decreased. For wedges, shreds, and gratings held 1 hour, ascorbic acid retention was 88, 61, and 24 percent, respectively.

When dehydroascorbic acid was included with the ascorbic acid, the retention figures were 97, 85, and 75, respectively, for wedges, shreds, and gratings. With increased exposure of carrot surface to the air, the difference between the retention of ascorbic plus dehydroascorbic acid increased. This showed that ascorbic acid was changed to dehydroascorbic faster than dehydroascorbic was destroyed.

The effect of increase in surface area (estimated) as related to decrease in ascorbic acid content is given in table 17.

Time of holding beyond the first hour apparently had less effect than surface area (table 18). Ascorbic acid retention of shreds was 78 percent immediately after shredding and 61, 62, and 57 percent after holding 1, 3, and 5 hours, respectively. Corresponding retention when dehydroascorbic acid was included was higher at every holding period. The figures were 88, 84, 74, and 69 percent, respectively. Thus, most of the loss of ascorbic acid occurred during the first hour. Oxidation of dehydroascorbic acid proceeded at a slower rate than its formation from ascorbic acid.

The results indicated that material in the knives and shredders had no effect on ascorbic acid. This was true even though the tissues were bruised to a greater degree by the plastic cutlery than by the sharper metal edges.

Summary and Conclusions on Carrots

Mature carrots of the Chantenay variety and young carrots of the Imperator variety purchased on the Washington, D. C., market were studied as to their nutritive value in relation to home cooking methods and preparation for serving raw. Both the raw and cooked carrots were analyzed for all or several of the following nutrients: Carotene, ascorbic acid, dehydroascorbic acid, nicotinic acid, moisture, and ash.

The cooking methods used were boiling, steaming, and cooking in a pressure saucepan. For serving raw, the carrots were cut in strips, wedges, shreds, or gratings. Cutlery made of stainless steel was compared with that made of plastic in its effect upon the ascorbic acid retained by the carrots. The effect of holding after preparation for serving raw was also studied with respect to retention of ascorbic acid.

The skin of the carrot, unlike that of the potato, played an unimportant role in conserving nutritive value. Carrots boiled whole, whether pared or unpared, retained about 90 percent of their ascorbic acid. Nicotinic acid was retained to a greater extent by boiling whole than by any other cooking method studied. Mineral matter was retained approximately 100 percent in the drained carrots.

The amount of cut surface exposed during boiling affected the retention of ascorbic acid. Boiling pared quartered carrots resulted in 80 percent retention, whereas those sliced crosswise retained 70 percent. That these losses were due almost entirely to heat and oxidation is indicated by the fact that little ascorbic acid was found in the residual liquid. The difference between the retention of ascorbic and dehydroascorbic acid was also affected by changes in surface exposed to water and air. The results suggest that as more surface was exposed more ascorbic acid was destroyed. Carotene was un-

affected in the carrots cooked this way. There was 100-percent retention of nicotinic acid and ash when the residual liquid was combined with the drained vegetable.

The volume of cooking water also influenced the retention of nutrients in the drained vegetable which had been either quartered lengthwise or sliced crosswise before boiling. Ascorbic acid retention in these forms was about 20 percent higher when the volume of cooking water was reduced one-half; whereas the carrots boiled whole were unaffected by the quantity of water. Carotene, as in the other cooked carrots, was unchanged. There was greater loss of nicotinic acid and ash from the carrots cooked in the larger quantity of water but it was recovered in the residual liquid.

For pared quartered carrots, steaming was a more effective way of conserving nutrients than boiling in water to cover. When half as much water was used for boiling, retention was the same as for steaming.

Cooking in a pressure saucepan also resulted in a high retention of nutrients. Carrots sliced crosswise retained about 20 percent more ascorbic acid than did carrots cut the same way and boiled. Also, these pressure-cooked slices retained about as much as did the carrots boiled whole.

Addition of salt to the water used for cooking the whole carrots had no influence upon ascorbic acid, but resulted in somewhat lower retention when the carrots were cooked quartered or sliced crosswise. Nicotinic acid retention in all but the crosswise slices was unaffected. There was a loss of mineral matter from the carrot into the water in the presence of salt.

In the carrots prepared for serving raw, it was found that as the cut surface area was increased from strips to wedges, to shreds, to gratings, retention of ascorbic acid decreased progressively from 100 to 24 percent.

Holding the shreds after cutting resulted in little if any loss of ascorbic acid after the first hour. The carrots retained 80 percent of this vitamin immediately after shredding, and about 60 percent after holding 1 hour. There was no further decrease up to 5 hours.

Plastic and metal cutlery when used for cutting, shredding, and grating of the carrots were similar in their effect on the ascorbic acid retention of the carrots.

Table 11.—Carrots (Chantenay variety): *Preparation and home cooking procedures, yield of product, and residual liquid*

Cooking method	Identification No.[1]	Size of raw sample (edible portion)	Water used in cooking	Ratio of carrots to water	Salt	Cooking time	Cooked yield	Residual cooking liquid
		Gm.	*Ml.*	*Gm. per ml.*	*Gm.*	*Min.*	*Gm.*	*Ml.*
Boiled covered:								
Unpared:								
Whole	2	680	400	1.71		40	641	208
Whole	4	680	800	.85		40	648	470
Pared:								
Whole	6	680	400	1.71		40	631	132
Quartered	8	680	300	2.27		30	646	116
Quartered	10	680	600	1.13		30	649	369
Sliced crosswise	12	680	250	2.72		18	664	103
Boiled covered, salted water:								
Unpared:								
Whole	14	680	400	1.71	4	40	644	162
Pared:								
Whole	16	680	400	1.71	4	40	628	111
Quartered	18	680	300	2.27	3	30	640	159
Sliced crosswise	20	680	250	2.72	2.5	18	664	47
Steamed:								
Pared, quartered	22	680	[2]2,000			30	641	[2]1,671
Cooked in pressure saucepan:								
Pared, sliced crosswise	24	680	[3]80	8.5		4	623	[3]34

[1] All samples, raw and cooked, are numbered. Only those for cooked samples appear in this table.

[2] In bottom part of steamer, not in direct contact with food.

[3] Below rack, not in direct contact with food.

Table 12.—Carrots (Chantenay variety): *Vitamin and ash content* [1] *per 100 grams dry weight, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Number of samples [3]	Moisture	Ascorbic acid	Ascorbic plus dehydroascorbic acid	Nicotinic acid	Ash
			Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Unpared: [4]							
Whole:							
Raw	1	9	87.8	36.9	52.0	6.2	7,300
Boiled covered, 40 min., 400 ml. water	2	9	87.8	35.6	49.4	6.2	7,300
Raw	3	1	87.5	29.9	44.0	4.8	7,300
Boiled covered, 40 min., 800 ml. water	4	1	87.0	28.8	43.8	5.8	7,600
Pared:							
Whole:							
Raw	5	2	87.3	34.8	53.7	7.1	6,800
Boiled covered, 40 min., 400 ml. water	6	2	87.2	32.5	53.2	5.9	6,600
Quartered:							
Raw	7	4	87.9	36.3	53.6	6.1	7,500
Boiled covered, 30 min., 300 ml. water	8	4	87.9	30.3	56.1	5.3	7,100
Raw	9	1	87.9	35.9	39.6	6.0	7,600
Boiled covered, 30 min., 600 ml. water	10	1	90.8	29.1	35.5	5.4	8,300
Sliced crosswise:							
Raw	11	3	87.7	37.9	49.4	6.5	7,400
Boiled covered, 18 min., 250 ml. water	12	3	88.0	28.9	48.4	6.1	7,100
Unpared: [4]							
Whole:							
Raw	13	2	87.5	33.7	50.9	7.8	6,500
Boiled covered, 40 min., 400 ml. water, 4 gm. salt added.	14	2	87.9	33.9	54.0	8.9	6,600
Pared:							
Whole:							
Raw	15	1	87.7	34.2	57.1	6.0	7,700
Boiled covered, 40 min., 400 ml. water, 4 gm. salt added.	16	1	86.6	31.2	51.8	4.8	9,600
Quartered:							
Raw	17	1	87.7	33.3	58.7	6.6	7,200
Boiled covered, 30 min., 300 ml. water, 3 gm. salt added.	18	1	88.3	23.8	56.4	5.8	9,000
Sliced crosswise:							
Raw	19	1	87.9	35.6	47.0	5.2	7,600
Boiled covered, 18 min., 250 ml. water, 2.5 gm. salt added.	20	1	87.7	18.5	28.4	5.0	8,400
Quartered:							
Raw	21	1	87.2	34.8	----	5.5	7,300
Steamed, 30 min	22	1	87.2	28.9	----	5.0	6,800
Sliced crosswise:							
Raw	23	1	87.6	36.4	41.6	7.2	7,300
Cooked in pressure saucepan, 4 min	24	1	86.4	33.2	46.9	6.6	7,100

[1] Values for cooked carrots based on drained weight.
[2] See table 11 for details of cooking method.
[3] Each sample represents 3 replicate raw or cooked portions.
[4] Raw samples were analyzed pared. Cooked samples were analyzed peeled, since the skin separated from the flesh easily without cutting.

Table 13.—Carrots (Chantenay variety): *Vitamin and ash content [1] per 100 grams wet weight, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Number of samples [3]	Moisture	Ascorbic acid	Ascorbic plus dehydroascorbic acid	Nicotinic acid	Ash
			Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Unpared: [4]							
Whole:							
Raw	1	9	87.8	4.5	6.3	0.76	891
Boiled covered, 40 min., 400 ml. water	2	9	87.8	4.3	6.0	.76	891
Raw	3	1	87.5	3.7	5.5	.60	912
Boiled covered, 40 min., 800 ml. water	4	1	87.0	3.7	5.7	.75	988
Pared:							
Whole:							
Raw	5	2	87.3	4.4	6.8	.90	864
Boiled covered, 40 min., 400 ml. water	6	2	87.2	4.2	6.8	.76	845
Quartered:							
Raw	7	4	87.9	4.4	6.5	.74	908
Boiled covered, 30 min., 300 ml. water	8	4	87.9	3.7	6.8	.64	859
Raw	9	1	87.9	4.3	4.8	.73	920
Boiled covered, 30 min., 600 ml. water	10	1	90.8	2.7	3.3	.50	764
Sliced crosswise:							
Raw	11	3	87.7	4.7	6.1	.80	910
Boiled covered, 18 min., 250 ml. water	12	3	88.0	3.5	5.8	.73	852
Unpared: [4]							
Whole:							
Raw	13	2	87.5	4.2	6.4	.98	812
Boiled covered, 40 min., 400 ml. water, 4 gm. salt added.	14	2	87.9	4.1	6.5	1.08	799
Pared:							
Whole:							
Raw	15	1	87.7	4.2	7.0	.74	947
Boiled covered, 40 min., 400 ml. water, 4 gm. salt added.	16	1	86.6	4.2	6.9	.64	1,286
Quartered:							
Raw	17	1	87.7	4.1	7.2	.81	886
Boiled covered, 30 min., 300 ml. water, 3 gm. salt added.	18	1	88.3	2.8	6.6	.68	1,053
Sliced crosswise:							
Raw	19	1	87.9	4.3	5.7	.63	920
Boiled covered, 18 min., 250 ml. water, 2.5 gm. salt added.	20	1	87.7	2.3	3.5	.62	1,033
Quartered:							
Raw	21	1	87.2	4.5		.70	934
Steamed, 30 min	22	1	87.2	3.7		.64	870
Sliced crosswise:							
Raw	23	1	87.6	4.5	5.2	.89	905
Cooked in pressure saucepan, 4 min	24	1	86.4	4.5	6.4	.90	966

[1] Value for cooked carrots based on drained weight.
[2] See table 11 for details of cooking method.
[3] Each sample represents 3 replicate raw or cooked portions.
[4] Raw samples were analyzed pared. Cooked samples were analyzed peeled, since the skin separated from the flesh easily without cutting.

Table 14.—Carrots (Chantenay variety): *Retention [1] of vitamins and ash, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Ascorbic acid		Ascorbic plus dehydroascorbic acid	Nicotinic acid		Ash	
		Carrots plus cooking liquid	Drained carrots	Drained carrots [3]	Carrots plus cooking liquid	Drained carrots	Carrots plus cooking liquid	Drained carrots
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Boiled covered:								
Unpared: [4]								
Whole, 40 min., 400 ml. water	2	93.1	91.0	90.8	116.0	94.0	108.6	93.8
Whole, 40 min., 800 ml. water	4	96.0	92.6	95.9	----	117.8	----	101.4
Pared:								
Whole, 40 min., 400 ml. water	6	94.8	90.4	103.0	97.2	80.0	107.6	96.1
Quartered, 30 min., 300 ml. water	8	81.1	78.8	97.4	96.3	80.6	101.7	88.0
Quartered, 30 min., 600 ml. water	10	62.3	58.9	65.2	92.8	65.4	104.0	79.7
Sliced crosswise, 18 min., 250 ml. water	12	72.0	69.5	93.8	98.0	85.6	96.8	86.9
Boiled covered, salted water:								
Unpared: [4]								
Whole, 40 min., 400 ml. water, 4 gm. salt added.	14	95.1	91.8	97.4	112.7	93.4	91.6	61.1
Pared:								
Whole, 40 min., 400 ml. water, 4 gm. salt added.	16	95.6	91.7	95.1	97.4	80.4	102.4	77.8
Quartered, 30 min., 300 ml. water, 3 gm. salt added.	18	70.6	64.1	85.0	97.1	79.7	97.9	75.0
Sliced crosswise, 18 min., 250 ml. water, 2.5 gm. salt added.	20	54.1	52.0	59.7	102.7	95.1	86.7	79.5
Steamed:								
Pared:								
Quartered, 30 min	22	80.0	78.2	----	97.8	86.6	96.6	87.9
Cooked in pressure saucepan:								
Pared:								
Sliced crosswise, 4 min	24	88.7	88.7	110.0	94.0	89.3	98.5	94.5

[1] Retention is calculated as follows: $\frac{\text{content per gm. cooked} \times \text{cooked weight (gm.)}}{\text{content per gm. raw} \times \text{raw weight (gm.)}} \times 100$.

[2] See table 11 for details of cooking methods.

[3] Cooking liquids were not analyzed for ascorbic plus dehydroascorbic acid.

[4] Analyzed peeled.

Table 15.—Raw Carrots (Imperator variety): *Vitamin and ash content per 100 grams dry weight and retention, [1] as affected by type of cut (area of surface exposed)*

Description	Identification No.	Number of samples [2]	Ascorbic acid [3]		Ascorbic plus dehydroascorbic acid [3]		Ash [3]	
			Content	Retention	Content	Retention	Content	Retention
			Mg.	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Pared:								
Quarters analyzed immediately [4]	25	5	47.9± 5.5	----	56.2± 6.0	----	6,430± 460	----
Strips cut with stainless steel knife, held 1 hr.	26	5	47.8±10.3	101.6	54.3± 9.0	101.1	6,530± 360	101.7
Strips cut with plastic knife, held 1 hr.	27	5	50.4± 7.0	104.0	58.1± 5.2	103.4	6,440± 390	99.1
Quarters analyzed immediately [5]	28	5	43.0± 9.6	----	50.8±18.0	----	6,960± 930	----
Wedges, tin-plated shredder, held 1 hr.	29	5	37.0± 7.7	87.5	48.3±15.1	96.7	6,800±1,000	98.7
Shreds, tin-plated shredder, held 1 hr.	30	5	25.8± 4.7	61.0	43.6±12.9	84.5	6,820± 901	97.6
Gratings, plastic grater, held 1 hr	31	5	10.3± 3.1	24.2	37.8±16.4	75.0	6,870±1,020	100.3

[1] Retention is calculated as follows: $\frac{\text{content per gm. after cutting} \times \text{weight after cutting (gm.)}}{\text{content per gm. before cutting} \times \text{weight before cutting (gm.)}} \times 100$.

[2] Each sample represents 3 or more replicate analyses.

[3] 90 percent of the values will fall within the designated limits when using the A. S. T. M. method for defining the limits of the certainty (*2*).

[4] Control for 26 and 27, used for calculating retention.

[5] Control for 29, 30, and 31, used for calculating retention.

Table 16.—Raw Carrots (Imperator variety): *Vitamin and ash content per 100 grams wet weight, as affected by type of cut (area of surface exposed)*

Description	Identification No.	Number of samples [1]	Ascorbic acid	Ascorbic plus dehydroascorbic acid	Ash
			Mg.	*Mg.*	*Mg.*
Pared:					
Quarters analyzed immediately	25	5	6.71	7.87	900
Strips cut with stainless steel knife, held 1 hr	26	5	6.79	7.71	927
Strips cut with plastic knife, held 1 hr	27	5	7.11	8.19	908
Quarters analyzed immediately	28	5	5.46	6.45	884
Wedges, tin-plated shredder, held 1 hr	29	5	4.88	6.38	898
Shreds, tin-plated shredder, held 1 hr	30	5	3.39	5.71	893
Gratings, plastic grater, held 1 hr	31	5	1.35	4.95	900

[1] Each sample represents 3 or more replicate analyses.

Table 17.—Raw Carrots (Imperator variety): *Ascorbic acid content as affected by type of cut (area of surface exposed)*

Type of cut	Number of pieces [1]	Surface area exposed [1]	Ascorbic acid (mg. per 100 gm. dry weight)
		Sq. in.	*Mg.*
Quarters	4	22.2	47.9
Strips	8	34.2	47.8
Wedges	130	45.0	37.0
Shreds	257	56.5	25.8
Gratings	2,532	129.0	10.3

[1] Estimated for a carrot 6 inches long and 1 inch in diameter at top.

Table 18.—Raw Carrots (Imperator variety): *Vitamin and ash content per 100 grams dry weight and retention [1] in carrot shreds, as affected by holding time*

Description	Identification No.	Number of samples [2]	Ascorbic acid		Ascorbic plus dehydroascorbic acid		Ash	
			Content	Retention	Content	Retention	Content	Retention
			Mg.	*Pct.*	*Mg.*	*Pct.*	*Mg.*	*Pct.*
Pared:								
Quarters, analyzed immediately	32	2	42.5		47.6		6,720	
Shreds, analyzed immediately	33	2	31.6	77.6	40.6	88.4	6,610	102.6
Quarters, analyzed immediately	34	5	42.8		51.0		6,970	
Shreds, held 1 hr	35	5	25.8	61.0	43.6	84.5	6,820	97.6
Quarters, analyzed immediately	36	3	39.7		44.2		6,720	
Shreds, held 3 hr	37	3	24.5	61.9	32.6	73.7	6,590	97.8
Shreds, held 5 hr	38	3	22.8	56.7	31.1	69.2	6,670	96.7

[1] Retention is calculated as follows: $\frac{\text{content per gm. after holding} \times \text{weight after holding (gm.)}}{\text{content per gm. before holding} \times \text{weight before holding (gm.)}} \times 100$.

[2] Each sample represents 3 or more replicate analyses.

GREEN PEAS

Peas in their green immature state are a favorite vegetable for cooking fresh or for canning or freezing. While peas are generally cooked quite simply in boiling water salted or unsalted, there is also the practice of adding baking soda (sodium bicarbonate) to the cooking water. Pressing peas through a sieve to make purees suitable for soups and for use in special diets has also become common. Naturally questions arise as to what effect these methods of preparation have on the nutritive value of the peas.

This study was undertaken to furnish at least some of the answers. In the study of fresh peas ascorbic acid, dehydroascorbic acid, thiamine, nicotinic acid, moisture, and ash were measured. Riboflavin was also determined, but results are not reported. (See Appendix C, p. 73.) In the study of frozen peas used for purees, all of the above nutrients except thiamine were determined.

Variety and Storage

Peas in the pod were purchased in nine different lots from those available on the Washington, D. C., market from June to October 1944. They were of the Telephone variety, grown in four States—California, Colorado, Idaho, and New York.

Frozen peas of an unknown variety, in 12-ounce packages, all from the same processed lot, were purchased in February 1945 and stored at 0° F. Packages were withdrawn as needed throughout the experimental period, which lasted through April 1945.

Preparation, Cooking, Sampling

Control of Cooking Conditions

Details of preparation, methods of cooking, weight of raw and cooked food, volume of water and residual liquid, and cooking time are presented in table 19. As in the case of the other vegetables, the peas were cooked in 680-gm. portions sufficient to furnish six servings. The quantity of water used was less than enough to cover but sufficient to prevent scorching. The peas were drained and cooled as described on page 2.

Each of the variations in preparation was accompanied by a control sample of plain boiled peas. This explains the large number of samples studied in the latter case. Attention was given to the effect of boiling fresh peas with and without addition of salt (sodium chloride) and of baking soda (sodium bicarbonate) to the cooking water. Also studied was the effect of making purees by different methods, using frozen peas.

Boiling fresh peas.—The peas were dropped into distilled water (see p. 2) that had been boiling 3 minutes to drive off dissolved gases. The peas were boiled gently in 3-quart covered enameled pans until tender. For each lot purchased, length of cooking time to produce a standard degree of doneness was determined in preliminary tests by several persons experienced in food judging. Objective tests for doneness, such as wire puncture and penetrometer, were tried but the judgment of experienced tasters proved more practicable.

In studies of the effect of boiling in salted water, the amount of salt was established by preliminary tasting tests. Three grams of salt, or ½ teaspoon, was added to 300 ml. of water before heating.

In studies of the effect of adding soda to the cooking water, the amount was also established by tasting as the minimum which preserved the color of the peas without affecting their flavor. For 680 gm. of peas, 0.44 gm. of soda, or less than ⅛ teaspoon, was added to 300 ml. water before heating.

Making purees.—Frozen peas were thawed in the package at room temperature overnight and cooked in distilled water as described under boiling fresh peas. The liquid from thawed peas drained by the method described on page 2 was included in the cooking water. In preliminary tests a standard cooking time was established

by persons experienced in food judging and was used throughout the experiments. The effect on retention of nutrients was studied for two types of sieve available during wartime, a common household tin-plated wire sieve and a food mill of acid-resistant steel. Both hot and cold cooked peas were used in making purees.

Sampling Methods

Fresh peas were shelled and spread out on an enameled tray. In order to simulate household conditions, the peas were not sorted for size. Spoonfuls were taken from various parts of the tray for the raw samples and for those to be cooked. The same method was used for subsampling the raw and cooked peas for determination of the specific nutrients. For making purees, 18 packages of the frozen peas were withdrawn from storage for each experiment, thawed, composited, and sampled as for fresh peas. For analysis, three 680-gm. portions of raw, cooked, or pureed peas were composited.

Methods of Analysis

Ascorbic acid, dehydroascorbic acid, thiamine, riboflavin, moisture, and ash of the raw and drained cooked food and residual cooking liquid were determined by methods described on pages 6 and 32. Nicotinic acid was measured by the microbiological method of Krehl, Strong, and Elvehjem (*43*), which employed an improved media.

The pH of cooking water before heating and of residual liquid was determined at laboratory temperature by glass electrode.

Results on Peas

Although of the same variety, fresh peas from the four States differed appreciably in vitamin content (table 20).

Average values for the nutrients studied are presented in table 21 on a wet-weight basis and in table 22 on a dry-weight basis. Ascorbic acid values ranged from 40 to 85 mg., thiamine from about 0.5 to 2.5 mg., and nicotinic acid from about 7 to 11 mg. per 100 gm. dry weight. The frozen peas which were thawed for use in purees averaged 59 mg. ascorbic acid, 69 mg. ascorbic plus dehydroascorbic acid, 9 mg. nicotinic acid, and 4,200 mg. ash per 100 gm. dry weight.

The difference between the standard deviations for the content of nutrients in the raw peas and the frozen peas indicate the frozen sample was more uniform except in the case of ash for which the standard deviations were about the same. Because of the variability of the raw Telephone peas, the average value for ascorbic acid plus dehydroascorbic acid does not present the true picture. Some of the raw samples contained much dehydroascorbic acid, but many others contained none. On the other hand all samples of frozen peas contained approximately the same amounts of dehydroascorbic acid.

The ascorbic acid content of the thawed frozen peas was lower than that of the raw fresh peas; whereas the ascorbic acid plus dehydroascorbic acid values were practically identical. This suggests that during processing some of the ascorbic acid was converted to dehydroascorbic acid.

Effect of Boiling Fresh Peas

In spite of the range in content values, percentage retention was remarkably constant for the three cooking methods studied (table 23).

Ascorbic acid.—Ascorbic acid retention in fresh peas cooked with and without salt or soda, averaged about 80 percent when cooking liquid was included. The drained peas retained about 70 percent after boiling in water alone, and about the same when salt or soda was added. This agreement was more marked when the retention for the control sample and its variant were compared on any given day. Thus, approximately 10 percent of the ascorbic acid in the raw peas was found in the cooking liquid and about 20 percent was apparently destroyed by heat and oxidation. Dehydroascorbic acid retention was very close to that obtained when ascorbic acid alone was considered. This indicated similar rates of transformation even in the presence of salt or soda.

Limited experiments on rate of change in ascorbic acid content of peas indicated that retention after 9 minutes' cooking in distilled water alone was within 5 percent of that found

after 18 minutes. Retention after 4 minutes' cooking in water with soda added was practically the same as that after 8 minutes. This indicates that the rate of change in ascorbic acid value was rapid in the early part of the cooking period and reached a level which stayed practically the same until the peas were judged "done" by the tasting panel. What happens after this stage of doneness (tender but firm) is reached in cooking peas with soda needs further investigation. The effect of the use of soda in the cooking of other vegetables also needs to be studied.

It is of interest that cooking time was 18 minutes for boiling with or without salt, but was only 8 minutes for boiling with soda. Thus, a very small amount of soda increased the rate of softening of peas so that they were cooked to doneness in less than half the time required for peas cooked without soda. The appearance of the cooked product was also better, especially when the initial color of the peas was not good. The color of the peas cooked just to doneness with the proportion of soda to water and peas used in these experiments was a bright natural green. Those cooked without soda were often an uneven dull green, particularly in the case of the more mature peas.

The pH of the distilled water before boiling ranged from 4.9 to 6.0, with an average of 5.6. The pH of the residual liquid, salted or unsalted, averaged 6.3, with a range of 5.7 to 6.7. When soda was used the pH of the residual liquid averaged 7.7, with a range of 7.2 to 8.9. The retention of ascorbic acid was the same regardless of the pH of the cooking liquid. In view of this same retention with the shorter cooking time, it should be noted that the rate of destruction was twice as fast in the presence of soda.

It is important to note that the pH of many water supplies is around 8.0 as compared to a pH of below 7.0 for the boiling distilled water in which peas were cooked in this experiment. Natural waters differ not only in pH but also in the kind and quantity of dissolved substances they contain. These may affect the final pH, nutritive value, and palatability, particularly when soda is added.

These observations on retention are similar to those reported by Johnston and coworkers (*39*) for peas and by Wadsworth and Wilcox for lima beans (*69*).

Thiamine.—After boiling, peas plus cooking liquid retained 75 percent thiamine; the drained peas, 70 percent. When salt or soda was used, the peas plus cooking liquid retained about 80 percent thiamine and the drained peas, about 75 percent. These results indicate that the loss of thiamine was due largely to destruction by heat since only about 5 percent of the vitamin was present in the residual liquid.

Nicotinic acid.—Regardless of how the peas were boiled, with or without salt or soda, they retained practically 90 percent of their nicotinic acid, when cooking liquid was included. The drained peas retained approximately 75 percent. It appears that about 15 percent of the nicotinic acid remained in the cooking liquid, while 10 percent was unaccounted for.

This discrepancy in the nicotinic acid figures is difficult to explain since this vitamin is stable to heat and oxidation. It was not ascertained whether the nicotinic acid values as determined for the raw peas were too high owing to stimulating factors or those of the cooked peas too low due to their absence. It is possible that some substances extracted into the cooking liquid interfered with the growth of the test microorganisms and resulted in low values for the cooking liquid. It may be that the substances which interfered with riboflavin determinations (see Appendix C, p. 73) also interfered with those of nicotinic acid.

Ash.—The retention of ash was close to 100 percent in all cases for peas plus cooking liquid, which indicated successful sampling. The drained peas retained 88 percent after cooking in water alone and 85 and 75 percent, respectively, when salt or soda was added to the water. This suggests that use of soda results in increased leaching of ash.

Effect of Boiling Frozen Peas

Ascorbic acid.—Cooked frozen peas averaged 37 mg. ascorbic acid and 43 mg. ascorbic plus dehydroascorbic acid per 100 gm. dry weight (table 22). This ascorbic acid value is lower than that for cooked fresh peas, but the values

for ascorbic plus dehydroascorbic acid are almost the same.

The retention of ascorbic acid for thawed frozen peas cooked 7 minutes was about 60 percent as compared with about 70 percent for fresh peas cooked 18 minutes in water alone or cooked 8 minutes in water containing soda (table 23). This lower retention may have been due in part to the fact that more of the frozen peas than the fresh had ruptured skins.

About 10 percent of the ascorbic acid was found in the cooking liquid; apparently 30 percent was destroyed by heat and oxidation. For fresh peas, corresponding percentages were about 10 and 20, respectively. The pH of the residual liquid for the boiled frozen peas was 6.5, similar to that for the boiled fresh peas.

These findings on boiled frozen peas are in agreement with those on lima beans in this study (p. 16), and also with those of Johnston and others (*39*) on frozen peas and Wadsworth and Wilcox (*69*) on frozen lima beans.

The retention of ascorbic plus dehydroascorbic acid was the same as for ascorbic acid alone. This indicates that dehydroascorbic acid was transformed at the same rate as ascorbic acid.

Nicotinic acid.—The average nicotinic acid content of cooked frozen peas was 8 mg. About 97 percent nicotinic acid was retained in the peas plus cooking liquid and 84 percent in the drained peas. It will be noted that the method of analysis used for nicotinic acid accounted more successfully for the vitamin retention in frozen peas than in the case of the fresh peas. Apparently no interfering substances were present in the frozen peas.

Ash.—The average ash content of cooked frozen peas was 4,000 mg. per 100 gm. dry weight. After cooking, ash was retained to approximately the same degree in frozen peas as in fresh peas. One hundred percent ash was retained in the peas plus cooking liquid and 88 percent in the drained peas.

The ash of the frozen peas was consistently slightly brown in color, suggesting the presence of iron, which might be due to contamination from the equipment used in processing the peas prior to freezing. If this is so, it may be another explanation of the lower retention of ascorbic acid in cooked frozen peas than in the fresh ones.

Effect of Making Purees

The ascorbic acid content of purees prepared from peas immediately after cooking was about 30 mg. per 100 gm. dry weight, when the food mill or the wire sieve was used. The corresponding values for purees from peas cooled after cooking were 37 mg. and 33 mg.

Retention of ascorbic acid, based on the value for thawed uncooked peas, was approximately 40 percent for hot peas pressed through the food mill or the wire sieve. It was approximately 50 percent when the cooked peas were cooled before pressing.

When the purees were made with the wire sieve, the resulting particle size was smaller than when made with the food mill. The time required with the wire sieve was 35 minutes for hot peas and 33 minutes for cold peas; with the food mill, corresponding times were 14 and 12 minutes. In spite of the different times and particle sizes there was no difference in retention of ascorbic acid or ascorbic plus dehydroascorbic acid. Apparently the initial equilibrium between ascorbic and dehydroascorbic acid remained unchanged.

With either sieve there was mechanical loss due to residual material that could not be forced through the openings. Retention values corrected for this loss are somewhat higher in each case than the uncorrected values. The loss of ascorbic acid ascribed to sieving alone was 5 percent for cold peas, 15 percent for hot peas. These figures are comparable to those for mashing potatoes (p. 37).

However, further research on making purees by home methods is needed before general conclusions can be drawn concerning the effect of different times, temperatures, and types of equipment on the nutritive value of the final product.

Summary and Conclusions on Peas

Fresh peas of the Telephone variety grown in four different States were purchased on the

Washington, D. C., market and were found to vary widely in vitamin content. They were boiled in distilled water with and without the addition of salt (sodium chloride) or soda (sodium bicarbonate).

Commercially frozen peas were bought on the Washington, D. C., market. They were used in a study of making purees by pressing hot and cold cooked peas through a wire sieve or a food mill.

Ascorbic acid, dehydroascorbic acid, thiamine, nicotinic acid, moisture, and ash were determined in raw and cooked fresh peas. With the exception of thiamine, the same nutrients were determined in frozen peas and in the purees.

When boiled in water, the drained fresh peas retained about 70 percent of the three vitamins —ascorbic acid, thiamine, and nicotinic acid— and somewhat more of their ash. Boiling in salted water made little difference in retention of these nutrients. Apparently much of the vitamin loss was in the early part of cooking.

When just enough soda was used to preserve the color of the peas without affecting natural flavor—slightly less than ⅛ teaspoon soda for 680 gm. of shelled peas and 300 ml. water—the retention of ascorbic acid and thiamine was the same as in peas cooked without soda. The cooking time was just sufficient to give a tender product. The use of this small amount of soda cut the cooking time approximately in half. General recommendations as to the use of soda in cooking vegetables must await further study on different vegetables and also study of the water in different localities.

The type of sieve used in making purees had little or no effect on the retention of ascorbic acid. Retention was less in purees made from hot cooked peas than from peas cooled before sieving.

Table 19.—Peas: ***Preparation and home cooking procedures, yield of product, and residual liquid***

Cooking method	Identification No. [1]	Size of raw sample (edible portion)	Water used in cooking	Ratio of peas to water	Cooking time	Salt	Baking soda [2]	Cooked yield	Residual cooking liquid
		Gm.	*Ml.*	*Gm. per ml.*	*Min.*	*Gm.*	*Gm.*	*Gm.*	*Ml.*
Fresh, raw:									
Boiled covered	2	680	300	2.27	18			640	171
Do [3]	3	680	300	2.27	9			652	193
Do	5	680	300	2.27	18	3		644	155
Do	7	680	300	2.27	8		0.44	658	214
Do [3]	8	680	300	2.27	4		.44	677	205
Frozen thawed:									
Boiled covered	10	680	[4]175	3.89	7			608	119

[1] All samples, raw and cooked, are numbered. Only those for cooked samples appear in this table.
[2] Sodium bicarbonate.
[3] Cooked half time for control purposes.
[4] Includes drained liquid from thawed peas.

Table 20.—Peas: ***Vitamin and ash content per 100 grams dry weight of peas (Telephone variety), grown in 4 States, as purchased on Washington, D. C., market***

State of origin	Date of purchase	Number of lots	Moisture	Ash	Ascorbic acid	Nicotinic acid	Thiamine
			Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*
California	June 1944	3	74.9	3,300	75.5	10.7	1.85
Colorado	Aug. and Sept. 1944	5	73.7	3,580	63.3	13.3	
Idaho	July 1944	2	78.4	3,780	80.0	10.5	.723
New York	July 1944	3	74.4	3,830	50.0	8.3	1.78

Table 21.—Peas: ***Vitamin and ash content [1] per 100 grams wet weight, as affected by various home cooking procedures***

Cooking method [2]	Identification No.	Number of samples [3]	Moisture	Ascorbic acid	Ascorbic plus dehydroascorbic acid	Thiamine [4]	Nicotinic acid	Ash
			Pct.	*Mg.*	*Mg.*	*Mg.*	*Mg.*	*Mg.*
Fresh (Telephone variety):								
Raw	1	13	74.8	16.4	17.2	0.365	2.4	910
Boiled covered, 18 min., 300 ml. water	2	11	73.9	12.0	12.3	.269	1.9	856
Raw	4	4	74.6	16.9	18.3	.452	2.5	889
Boiled covered, 18 min., 300 ml. water, 3 gm. salt added.	5	4	73.8	12.2	12.7	.348	2.0	1,056
Raw	6	8	74.6	15.2	16.2	.315	2.4	947
Boiled covered, 8 min., 300 ml. water, 0.44 gm. baking soda [5] added.	7	8	74.3	11.5	11.7	.250	1.9	874
Frozen (commercial):								
Thawed	9	15	80.7	11.4	13.3		1.7	812
Thawed, boiled covered, 7 min., 175 ml. water.	10	15	80.0	7.3	8.7		1.6	800
Made into puree:								
Pressed hot through food mill	10a	3	79.6	5.9	7.6			810
Pressed hot through wire sieve	10b	4	79.4	6.2	7.2		1.5	799
Pressed cold through food mill	10c	4	80.6	7.1	8.5		1.6	793
Pressed cold through wire sieve	10d	3	79.6	6.8	7.3		1.5	847

[1] Values for cooked and frozen peas based on drained weight.
[2] See table 19 for details of cooking method.
[3] Each sample represents 3 replicate raw or cooked portions.
[4] See discussion of these values under results.
[5] Sodium bicarbonate.

Table 22.—Peas: *Vitamin and ash content [1] per 100 grams dry weight, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Number of samples [3]	Ascorbic acid		Ascorbic plus dehydroascorbic acid		Thiamine [4]	Nicotinic acid		Total solids [5]	Ash	
			Milligrams	Standard deviation	Milligrams	Standard deviation	Milligrams	Milligrams	Standard deviation	Percent	Milligrams	Standard deviation
Fresh (Telephone variety):												
Raw	1	13	65.0	14.1	68.3	15.6	1.450	9.6	1.2	25.2	3,610	260
Boiled covered, 18 min., 300 ml. water	2	11	45.9	10.8	47.2	11.0	1.030	7.3	.8	26.1	3,280	80
Raw	4	4	66.4	19.6	72.0	24.5	1.780	9.7	2.0	25.4	3,500	410
Boiled covered, 18 min., 300 ml. water, 3 gm. salt added.	5	4	46.6	13.6	48.6	14.5	1.330	7.5	1.6	26.2	4,030	110
Raw	6	8	59.8	13.6	63.8	15.0	1.240	9.3	1.3	25.4	3,730	200
Boiled covered, 8 min., 300 ml. water, 0.44 gm. baking soda [6] added.	7	8	44.8	10.8	45.4	11.4	.974	7.3	1.1	25.7	3,400	220
Frozen (commercial):												
Thawed	9	15	58.9	3.6	69.1	7.0	----------	8.6	.2	19.3	4,210	240
Thawed, boiled covered, 7 min., 175 ml. water	10	15	36.6	2.8	43.3	6.4	----------	7.9	.3	20.0	4,000	220
Made into puree:												
Pressed hot through food mill	10a	3	29.0	2.2	37.1	2.4	----------	----------	----------	20.4	3,970	270
Pressed hot through wire sieve	10b	4	30.0	1.1	34.9	1.8	----------	7.5	----------	20.6	3,880	170
Pressed cold through food mill	10c	4	36.7	5.5	43.9	5.2	----------	8.1	----------	19.4	4,090	180
Pressed cold through wire sieve	10d	3	33.2	.6	35.7	3.4	----------	7.5	----------	20.4	4,150	290

[1] Values for cooked and frozen peas based on drained weight.
[2] See table 19 for details of cooking method.
[3] Each sample represents 3 replicate raw or cooked portions.
[4] See discussion of these values under results.
[5] Total solids figures are given instead of moisture to facilitate comparisons of total solids retention in table 23.
[6] Sodium bicarbonate.

Table 23.—Peas: *Retention [1] of vitamins and ash, as affected by various home cooking procedures*

Cooking method [2]	Identification No.	Ascorbic acid		Ascorbic plus dehydroascorbic acid		Thiamine		Nicotinic acid		Total solids		Ash	
		Peas plus cooking liquid	Drained peas	Peas plus cooking liquid	Drained peas	Peas plus cooking liquid	Drained peas	Peas plus cooking liquid	Drained peas	Peas plus cooking liquid	Drained peas	Peas plus cooking liquid	Drained peas
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Fresh, raw (Telephone variety):													
Boiled covered, 18 min., 300 ml. water.	2	81.6	68.7	85.1	65.9	74.9	69.7	89.1	74.6	100.9	97.2	101.8	88.2
Boiled covered, 18 min., 300 ml. water, 3 gm. salt added.	5	82.4	73.1		66.7	79.3	72.8	87.7	76.3	98.0	97.2	95.7	85.1
Boiled covered, 8 min., 300 ml. water, 0.44 gm. baking soda [3] added.	7	82.1	68.4	85.6	69.3	78.8	75.2	88.6	74.8	98.8	97.0	94.0	74.9
Frozen, raw (commercial):													
Thawed, boiled covered, 7 min., 175 ml. water.	10	66.4	57.4	66.8	57.9			96.7	83.6	95.9	92.3	100.0	87.6
Made into puree:													
Pressed hot through food mill	10a		42.8		45.4						84.4		80.5
Pressed hot through wire sieve	10b		44.3		42.3				76.8		87.6		83.3
Pressed cold through food mill	10c		50.7		51.6				79.8		83.6		80.5
Pressed cold through wire sieve	10d		50.0		47.9				75.4		86.6		83.2
Made into puree (corrected for weight of residue):													
Pressed hot through food mill	10a		46.1		48.9						91.0		87.1
Pressed hot through wire sieve	10b		47.3		45.2				82.4		93.6		88.6
Pressed cold through food mill	10c		54.7		55.8				85.9		91.0		85.9
Pressed cold through wire sieve	10d		52.8		50.7				78.9		91.5		87.9

[1] Retention is calculated as follows: $\frac{\text{content per gm. cooked} \times \text{cooked weight (gm.)}}{\text{content per gm. raw} \times \text{raw weight (gm.)}} \times 100$.

[2] See table 19 for details of cooking methods.

[3] Sodium bicarbonate.

GENERAL SUMMARY

Marked progress is being made in increasing the nutritive value of many foods by improvements in production and marketing. The extent to which the consumer benefits by these gains, however, often depends on the way the food is prepared for the table. This study was undertaken to measure some effects of common methods of household preparation on the vitamin and mineral content of a group of foods typical of those brought into the home kitchen.

Preliminary study was carried out on 20 foods, including vegetables, meats, poultry, breads, and cereals. More extensive studies were made on potatoes, carrots, and peas.

The nutrients determined were: Ascorbic acid, dehydroascorbic acid, carotene, thiamine, nicotinic acid, riboflavin, ash, calcium, phosphorus, iron, and moisture. For some of the foods, not all these nutrients were determined.

Sampling and methods of handling the foods were controlled so as to minimize destruction of ascorbic acid. Adequacy of the sampling was appraised by the degree of retention of such stable nutrients as ash and nicotinic acid in the drained food plus residual liquid.

The methods of preparation and cooking used were: Boiling, baking, steaming, cooking in a pressure saucepan, simmering, braising, and frying. All procedures were standardized. Carrots for serving raw as in salads were prepared in four different ways, as strips, wedges, shreds, and gratings. In the detailed investigation on potatoes, carrots, and peas, one or more of the following procedures were included: The use of salt and soda in boiling; soaking the food prior to cooking; holding it raw and cooked; mashing; use of plastic and metal cutlery; making purees with wire sieve and food mill.

In general, the results demonstrate that under controlled conditions it is possible to obtain reproducible results in studies of the effect of preparation and cooking on nutritive value.

With all the preparation methods used, the cooked foods retained less of their ascorbic acid and thiamine than of the other nutrients studied. Retention of ascorbic acid from pared and cut vegetables varied with the extent of surface exposed to the action of air or water. However, purees and mashed vegetables retained only slightly less ascorbic acid than the boiled vegetables. Thiamine, riboflavin, nicotinic acid, and minerals were also affected; losses due to extraction into the cooking water were proportionate to the quantity of water used.

Salt in the cooking liquid seemed to accelerate destruction of ascorbic acid. Use of soda under conditions of this experiment decreased the cooking time and resulted in approximately the same retention of nutrients as cooking without soda. The kind of cutlery and sieves used appeared to have no effect on ascorbic acid.

In potatoes, the skin proved extremely effective in conserving nutrients during cooking. In retention of nutritive value, baking potatoes whole in the skins ranked next to boiling them in the skins. Of all the cooking methods used with potatoes, frying was found to be the most destructive of ascorbic acid and thiamine.

Retention of ascorbic acid in terms of ascorbic or ascorbic plus dehydroascorbic acid was the same in potatoes and in peas. This fact suggests that degradation of dehydroascorbic acid takes place as rapidly as it is formed from ascorbic acid. During the holding of cooked potatoes, dehydroascorbic acid increased in proportion to the decrease of ascorbic acid. This indicates that some ascorbic acid is transformed into dehydroascorbic, which appears to be stable under the conditions of holding.

Interfering substances were encountered in the determination of ascorbic acid, thiamine, and riboflavin in certain samples of raw and cooked potatoes, carrots, and peas. Tests for protein-bound ascorbic acid gave negative results. In case of potatoes, measurement of reductones permitted correction for the presence of these interfering substances and "true" ascorbic acid values were obtained.

In the course of the study, a number of improvements in methods of analysis were developed. Among these was a modified method for measuring reductones. The procedure for digesting beans was modified, and resulted in more effective extraction of riboflavin. A rapid and inexpensive method using infrared lamps to determine moisture was developed. A formula was devised and used successfully as a basis for calculating vitamin and mineral retention.

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Appendix A

A SIMPLE AND RAPID METHOD FOR MOISTURE DETERMINATION USING INFRARED LAMPS[4]

When assaying foods for vitamin content a rapid method for moisture determination is desirable. A method was devised for this purpose in which infrared lamps were used as a source of heat.

As indicated in figure 2, five reflector-type, infrared heat lamps, 250 watt, 100-115 volts, were arranged, one at each corner and one in the center of a piece of 22-gage steel, 18 inches square. These were suspended 6 to 8 inches above a second square of 22-gage steel upon which the moisture dishes or crucibles were placed.

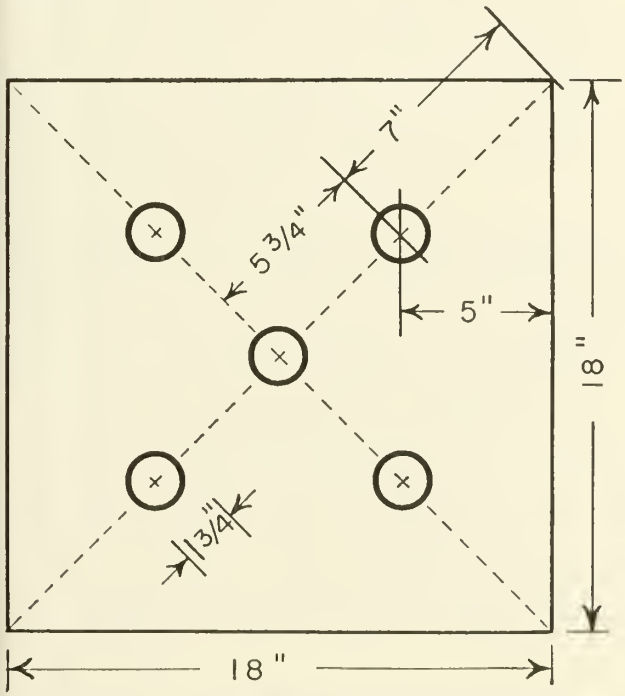

Figure 2.—Scale diagram for arrangement of infrared lamps.

Tables 24 and 25 give comparisons of moisture content as determined by air-oven, infrared lamps, and vacuum oven.

[4] Previously issued as National Cooperative Project for the Conservation of the Nutritive Value of Foods. BHN&HE Progress Notes No. 3. 1946. [Processed.]

By means of the five infrared lamps it is possible to dry 30 samples to constant weight at one time. A single infrared lamp dries 3 to 4 samples at one time.

Table 24.—*Moisture content of potatoes and carrots as determined by air oven at 100° C. and by infrared apparatus*

Sample	Air-oven method	Infrared-heat method
	Percent	*Percent*
Potatoes:		
Mashed	80.28	80.38
	80.42	
	80.30	
Average	80.3	80.4
Carrots:		
Raw	89.99	89.22
	89.60	89.09
Average	89.8	89.2
Peeled, quartered, boiled	89.18	89.14
	88.86	89.02
Average	89.0	89.1
Peeled, quartered, boiled	89.09	88.59
	89.12	88.70
Average	89.1	88.6
Peeled, sliced, cooked in pressure saucepan	88.42	88.62
	88.43	88.61
Average	88.4	88.6
Peeled, sliced, cooked in pressure saucepan	88.86	88.74
	88.81	88.80
Average	88.8	88.8

Table 25.—*Moisture content of potatoes as determined by air oven at 100° C. and by vacuum oven at 60° C.*

Sample	Air-oven method	Vacuum-oven method
	Percent	*Percent*
Potatoes:		
Mashed	80.50	79.96
		80.02
Average	80.5	80.0
Mashed	79.66	79.25
		79.25
Average	79.7	79.2
Boiled, whole, unpeeled	80.06	80.93
		79.63
Average	80.1	80.3
Peeled, quartered, boiled	79.46	80.75
		79.34
Average	79.5	80.0
Peeled, quartered, cooked in pressure saucepan.	80.48	78.49
	79.46	
Average	80.0	78.5

The drying time varies from 15 to 90 minutes, depending upon the kind of food. For best results the food product is cut as thin as possible since thick pieces tend to case harden. Liquids can also be evaporated quickly. Table 26 shows the rate of evaporation of distilled water and sodium chloride solutions.

By the use of the infrared apparatus it is possible to complete moisture determinations simultaneously with ascorbic acid analyses.

Table 26.—*Rate of evaporation of liquids* [1] *with infrared apparatus*

Volume of liquid	Diameter of vessel	Time to dryness
Ml.	*Mm.*	*Min.*
10	55	15
10	55	15
25	55	68
50	55	130
100	110	125
25	55	39

[1] Distilled water except the last sample, which was a saturated sodium chloride solution.

Appendix B

EXTRACTION OF RIBOFLAVIN FROM NAVY BEANS[5]

Wide variations in riboflavin values obtained by different methods of analysis have been reported for dry beans. In this study, analyses for riboflavin in dry navy beans obtained by the fluorometric method gave consistently higher results for the cooked than for the raw beans. This lack of agreement was apparently due to incomplete extraction. A procedure for complete extraction of riboflavin from navy beans was developed.

Materials, Methods, Procedures

The analyses reported here are those for which values are given in table 27.

For analysis, the raw or baked beans were ground to permit thorough mixing. Any particles left in the grinder were removed and in the case of the cooked beans, the cooking water was mixed with the ground beans.

The ground mixture was extracted in a macroblendor with 0.15 N sulfuric acid, aliquots from this mixture were weighed and diluted further with acid. They were then autoclaved for 15 minutes at 15 pounds pressure. After autoclaving, the pH of the solutions was adjusted to 2, and pepsin in pH 2 buffer was added. The solutions were incubated overnight at 37° C. They were then cooled to room temperature, the pH was readjusted to 4.0, and takadiastase in pH 4 buffer was added. After digesting for 8 to 10 hours, the solutions were centrifuged, filtered, when necessary, through glass wool, and made up to volume.

Riboflavin was determined on an aliquot of the solution after oxidation with potassium permanganate and destruction of the latter with hydrogen peroxide (*19*). The aliquot was then adsorbed on a florisil column. The column was washed with 200 ml. of wash solution at pH 4, and the riboflavin was eluted with aqueous pyridine acetic acid solution. The riboflavin fluorescence was then read in a Coleman (Model 12) fluorophotometer with the filters furnished for riboflavin determinations.

The results were corrected for adsorption by reading from a standard curve obtained by adsorbing pure riboflavin solutions under the same conditions as those used for analysis of the beans. The resulting values were consistently higher for the cooked than the raw beans (table 27). The values for each lot represent the average of the results obtained with two different size samples, as many as three aliquots being assayed for each sample.

It was evident from the data obtained in these experiments that extraction of the riboflavin, from both raw and cooked beans, was incomplete.

Table 27.—*Riboflavin content of navy beans, with 0.15 N sulfuric acid as extractant*

Method of preparation	Riboflavin (mcg. per gm. dry wt.)	
	Lot 1	Lot 2
Raw	4.2	6.2
Boiled ½ hr., then baked 6 hr. at 250° F.	5.5	9.1
Boiled 2 hr., then baked ½ hr. at 350° F.	5.8	8.6

In studying the digestibility of dry navy beans, Bowman (*14*) observed that the oil of these beans retarded the digestion in vitro of soluble starch by pancreatic amylase. Later studies regarding factors in navy beans that influence digestion showed that navy beans contain a fraction which inhibits the in vitro enzymatic digestion of casein (*15*). Also Lantz (*47*) in assaying pinto beans for riboflavin, found that rats were unable to utilize the riboflavin of the beans in the raw state, but that cooking made it available.

Therefore, another experiment, modifying the procedure for digesting the beans, was de-

[5] Previously issued as National Cooperative Project for the Conservation of the Nutritive Value of Foods. BHN&HE Progress Notes No. 2. 1946. [Processed.]

signed. Raw beans only were studied. The new technique substituted constant boiling 6.1 N hydrochloric acid for the 0.15 N sulfuric acid used in the first series of experiments. Hydrochloric acid was used rather than more concentrated sulfuric because it caused much less charring. Autoclaving for 15 minutes and digestion on the steam bath with stirring for 1 hour was tried. The results obtained by this modified procedure are presented in table 28.

It will be noted that with 0.15 N sulfuric acid, increase in size of the sample decreases the assay value. With more concentrated acid the drift with increasing sample size stops. When, in addition, vigorous agitation is introduced with the stronger acid, a marked increase in the value of the riboflavin resulted for both large and small samples and in agreement between the samples.

Bowman's observations show that it is a protein fraction separated from navy beans (*15*) which inhibits enzymatic digestion and which may account for the low nutritive values of raw beans. The findings reported in this paper suggest further that riboflavin may be bound in such a protein fraction, and that the vitamin is not released by the usual treatment with acid or enzymes. However, digestion with stronger acids, combined with mechanical stirring, seems to break down this protein complex, thus releasing the riboflavin.

Table 28.—*Riboflavin content of raw navy beans, with acids of different concentrations as extractants*

Digestion procedure	Enzyme (1 gm.)	Size of sample (gm.)	Riboflavin content (mcg. per gm. dry wt.)
0.15 N H_2SO_4, autoclaved.	Pepsin (pH 2) and takadiastase (pH 4).	10	4.8
		10	4.3
		20	2.7
		20	2.7
	Polidase S(pH 4).	20	3.5
		20	4.2
6.1 N HCl, constant boiling, auto claved.	Pepsin (pH 2) and takadiastase (pH 4).	10	7.5
		10	7.5
	Polidase S(pH 4).	20	7.0
		20	6.5
		20	6.3
	Mylase P(pH 4).	20	7.2
6.1 N HCl, steam bath with stirring 1 hr.	Pepsin (pH 2) and takadiastase (pH 4).	10	12.7
		10	10.2
	Mylase P(pH 4).	20	11.1
		20	11.3

Appendix C

INTERFERING SUBSTANCES IN THE DETERMINATION OF RIBOFLAVIN IN FRESH AND COOKED PEAS

In the study of Telephone peas riboflavin was included in the plans of analysis. The figures for riboflavin content of peas are not presented because the methods in use at the time were not suitable. Although the methods used were satisfactory in the study of 20 foods which included dry peas, difficulties were encountered with fresh peas. Material available was used up in developing satisfactory methods for analysis. However, the experience with existing methods afforded a number of observations that may have important bearing on future efforts to devise procedures for analysis of peas or other vegetables presenting the same difficulties.

After the vegetable material had been digested with acid and enzymes, the protein was precipitated from these extracts. Aliquots were withdrawn for thiamine analysis.

Determination of riboflavin in aliquots of the extract was attempted first with a microbiological method (*64*, *66*) and a chemical method (*19*, *26*). The lack of agreement within the determinations for a given method as well as between the two methods indicated interfering substances (table 29).

Table 29.—*Riboflavin content (mg. per 100 gm. wet weight of peas) by two methods*

Method of analysis and sample number	Size of sample	Content
	Gm.	*Mg.*
Microbiological:		
Undiluted:		
1a	9.95	0.178
1b	15.20	.136
Diluted 1:1:		
1a′	4.97	.141
1b′	7.60	.118
Chemical:		
Values read from standard curves:		
2a	10	.310
2b	20	.260
Values corrected for recovery of riboflavin added to control at beginning:		
2a′	10	.391
2b′	20	.327
Values corrected for recovery of riboflavin added to cuvette:		
2a″	10	.500
2b″	20	.672

At the time these analyses were undertaken McLaren, Cover, and Pearson (*51*) had proposed a simplified fluorometric method for riboflavin in meat. Sodium hydroxide added to a sample in a cuvette to pH 11 was used to destroy any riboflavin present. According to the findings of Kuhn and others (*44*, *46*) substances other than riboflavin should continue to fluoresce and so make possible a correction. When sodium hydroxide was applied to the samples of peas, fluorescence was greatly increased. In one sample, a reading of 16.6 scale divisions was increased to one of 30.2 at pH 11. Another sample gave a reading of 30.0 scale divisions before and 50.3 scale divisions after treatment with sodium hydroxide.

Adsorption on florisil or superfiltrol followed by elution with pyridine-acetic acid gave an eluate which also fluoresced more strongly with sodium hydroxide. This indicated that the interfering substances were adsorbed and eluted in a manner similar to riboflavin. Florisil gave more reproducible recoveries of pure riboflavin solutions than superfiltrol.

In an earlier permanganate method (*42*, *19*) oxidation is so controlled that the pigments other than riboflavin are destroyed. This leaves only the fluorescence due to riboflavin. Although this method had been used successfully for other foods in this laboratory (see p. 7), it failed to destroy the interfering pigments in peas. The same readings were obtained after oxidation as before, which showed that the interfering substances were as stable as pure riboflavin. When sodium hydroxide was added to the cuvette containing the sample oxidized with permanganate, the increased fluorescence was again observed. Combining the sodium hydroxide treatment with adsorption before and after permanganate oxidation indicated that the interfering sub-

stances were still present. Further oxidation with permanganate indicated that these substances were more stable than riboflavin toward permanganate, but not enough more stable so that riboflavin could be completely destroyed.

In the sodium hydrosulfite-stannous chloride method, all the fluorescing substances are reduced to nonfluorescing forms (*35*). Shaking the extract vigorously in air reoxidizes only the riboflavin to the fluorescing form. A sample of the extract of peas treated by this method also gave the same readings before and after hydrosulfite treatment. Use of sodium hydroxide after the hydrosulfite treatment again gave increased fluorescence.

From these reactions it was evident that a substance or substances were present which were very similar to riboflavin in their behavior as regards oxidation, reduction, adsorption, elution, and fluorescence. In addition this interfering fluorescence was not additive and decreased the fluorescence of any riboflavin present as was demonstrated in the recovery samples.

The amount of sample available from any one lot was limited and there was no certainty that the interfering substances were the same from lot to lot. This meant that aliquots taken for testing had to be kept at a minimum. In following all the various steps it was necessary to test supernatant liquids after adsorption, washings, and elutions. These volumes also had to be kept at a minimum.

Because of the necessarily small volumes, adsorption and elutions were carried out with bottles instead of columns as containers for adsorbents (*25*, *38*, *40*, *70*). The use of bottles was found to have other advantages. They made possible uniform shaking times for adsorption, washing, and elution. By this means only 0.1 to 1.0 gm. of adsorbent was needed and as little as 15 ml. of solute, followed by two 5-ml. portions, for washings and elutions. Adsorbent and supernatant liquid, adsorbent and washings, adsorbent and eluate could be easily separated by decantation, and any grains of adsorbent that floated off could be recovered by centrifuging. The use of bottles obviated another difficulty sometimes encountered in eluting riboflavin from columns. Unless all the wash water is removed from a column by suction, both the composition and pH of the eluting agent may be affected. The fluorescence of riboflavin changes with changes in pH (*45*). Ease of eluting is affected if the column dries out too much.

Table 30.—*Fluorescence of certain samples of peas as affected by treatment with Brockman's alumina*

Sample No.	Size of sample	Fluorescence [1]			
		Scale divisions before alumina		Scale divisions after alumina	
		Before NaOH	After NaOH	Before NaOH	After NaOH
	Gm.				
100	20.4	19.0	21.5	14.9	9.1
101	20.4 (50 mcg. riboflavin added)	39.6	25.5	39.6	8.2
102	40.2	28.0	30.6	21.6	15.1

[1] Instrument set so that 0.4 mcg. per ml. of riboflavin gave a reading of 60 scale divisions. Depending upon the pH of the solution measured, the standard used to set the instrument was the same pH.

The results of these experiments indicated that new adsorbents or eluting agents should be tried. Preliminary tests showed that Brockman's alumina did not adsorb pure riboflavin solutions, but did lower the readings of the samples of peas. However the values observed were not in proportion to the size of the sample as will be seen in table 30 above.

There was as yet no proof that all the interference was removed. At all times it was necessary to carry on parallel dilution experiments to determine whether the results obtained were due to dilution only or whether the adsorbents were effective.

In view of the effect of alumina it was decided to follow treatment with alumina by adsorption on superfiltrol or florisil shown below.

Details of experiment:	*Sample 74*	*Sample 75*	*Sample 76*
No adsorbent:			
Size of sample (gm.)	20.8	20.8	40.0
Added riboflavin (mcg.)	0	50	0
Volume (ml.)	250	250	250
Original reading at pH 4 (scale divisions)	26.0	48.2	30.0
Reading after sodium hydroxide pH 11 (scale divisions)	28.5	45.3	45.9

Alumina:			
75 ml. of each solution shaken 3 times with 3 gm. of Al_2O_3 and made to 100 ml.—			
Reading for supernatant from Al_2O_3 (scale divisions)	14.3	31.7	13.5
Reading after sodium hydroxide (scale divisions)	13.2	16.8	—
Difference	1.1	14.9	
Superfiltrol:			
50 ml. aliquot of each supernatant shaken with 0.1 gm. superfiltrol and eluted with 20 ml. of pyridine-acetic acid (20:2 percent), final volume 25 ml.—			
Reading for eluate from superfiltrol (scale divisions)	8.7	31.1	18.3
Reading after sodium hydroxide (scale divisions)	1.8	.8	1.7
Difference	6.9	30.3	16.6

In the case of the superfiltrol the reading for the large sample was slightly higher than it should have been in relation to the small sample, and the recovery of added riboflavin was low.

With alumina and florisil the following results were obtained:

Details of experiment:	*Sample 137*	*Sample 138*	*Sample 139*
No adsorbent:			
Size of sample (gm.)	9.74	9.74	14.8
Added riboflavin (mcg.)	0	50	0
Volume (ml.)	250	250	250
Original reading at pH 4 (scale divisions)	12.2	42.2	25.6
Reading after sodium hydroxide (scale divisions)	21.6	19.8	31.3
Alumina:			
75 ml. of each solution shaken 3 times with 3 gm. Al_2O_3 and made to final volume of 100 ml.—			
Reading for supernatant from Al_2O_3 (scale divisions)	13.1	34.2	18.1
Reading after sodium hydroxide (scale divisions)	9.4	9.6	13.8
Florisil:			
50 ml. of each supernatant from Al_2O_3 was shaken with 1 gm. of florisil—			
Reading for supernatant from florisil (scale divisions)	1.6	2.0	1.9
Reading after sodium hydroxide (scale divisions)	5.2	5.2	8.5
Florisil was eluted with pyridine-acetic acid (20:2 percent) and made to 25 ml. volume—			
Reading for eluate (scale divisions)	15.0	60.0	22.5
Reading after sodium hydroxide (scale divisions)	9.4	9.5	13.6
Difference	5.6	50.5	8.9

With the use of florisil the ratio of the weights of the small and large samples was 0.66 and of their respective fluorescence reading was 0.63. The line through these points passed almost through the origin. The recovery of added riboflavin was almost 100 percent; 44.9 scale divisions were found when the theoretical reading would have been 45.

These results suggested that a satisfactory method had been developed. However, sodium hydroxide no longer gave the greatly intensified fluorescence which had served to indicate the presence of the interfering substances. Even though enough of the interference could be removed by alumina adsorption to give a much lower reading than the original sample, the values were not necessarily correct because these interfering substances did not fluoresce in proportion to their concentration. The discrepancy was especially evident when this technique was applied to cooked peas. For example, the plotting of fluorescence readings against weight gave a line showing overcompensation, since the line passed to the right of the origin. However, it passed closer to the origin than the line for the uncorrected fluorescence readings of the original samples.

The findings indicated that some means other than the use of sodium hydroxide was necessary to obtain a figure for correction purposes. Irradiation has been used as a means of destroying riboflavin and obtaining such a correction. In these samples, however, the riboflavin seemed to be protected to a certain extent so that the fluorescence decreased very slowly. Treatment with sodium hydroxide after irradiation gave the usual increase in fluorescence.

Since Kuhn and others (44) had observed that concentrated acid as well as sodium hydroxide destroyed riboflavin, concentrated sulfuric acid was tried to obtain a reading for the blank.

It was necessary to add the concentrated acid (about 25 drops) slowly to a sample in a beaker. The sample was kept cool. It was observed that the sulfuric acid made no change in volume. In direct readings on samples the sulfuric acid blank was never higher than the original readings. Interference was still present, however, since readings for the large and small samples were not proportional.

Alumina adsorption alone was not sufficient in conjunction with the sulfuric acid blank to correct for interferences. Alumina followed by florisil adsorption with elution in conjunction with sulfuric acid served to correct some samples. This treatment was also successful for residual cooking liquids. However, there was never enough residual liquid to repeat on a larger sample. But two dilutions were tested and where the modification was successful, the values obtained were in agreement. Before treatment the values for two dilutions did not agree.

Another adsorbent, dicalcium phosphate ($CaHPO_4.2H_2O$), showed promise in overcoming these difficulties. Like alumina, dicalcium phosphate used alone removed part of the interfering substances. For some samples alumina and dicalcium phosphate gave identical results. With others, treatment first with dicalcium phosphate and then with alumina gave practically 100-percent recovery of added riboflavin without having to use florisil. Results from large and small samples were more nearly proportional.

Magnesium oxide also proved to be a good adsorbent for pure riboflavin. Shaking solutions with magnesium oxide resulted in a pH of around 9.5. At this pH the fluorescence of riboflavin was decreased, but adjustment to pH 4 or 6 gave values which agreed with those usually obtained for the standard curves at pH 4 or 6.

It was possible to elute pure riboflavin quantitatively from magnesium oxide with pyridine-sulfuric acid as well as with the commonly used pyridine-acetic acid. Recovery was 80 percent with both eluants. Part of this recovery may have been due to solution of magnesium oxide, since it was later found that if the magnesium oxide was dissolved in acid, all the riboflavin originally adsorbed was recovered. This procedure was reproducible for various concentrations of riboflavin so that a standard curve could be prepared to interpret results when magnesium oxide was used as the adsorbent.

When magnesium oxide was used as an adsorbent with extracts from peas, it was successful in helping to eliminate interfering substances. Part of this was apparently actual destruction of the interference since not all the original fluorescence was present after dissolving the magnesium oxide in acid.

From these series of observations, the interfering fluorescent substances found to be so similar to riboflavin in chemical behavior appeared to differ somewhat from one lot of peas to another. In some samples successful corrections were possible by the use of alumina and florisil with sulfuric acid. In others some combination of other adsorbents proved more effective. In all cases the sulfuric acid treatment was necessary to obtain a blank for correction.

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